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THE CHEMISTRY OF POTTERY

SIMEON SHAW

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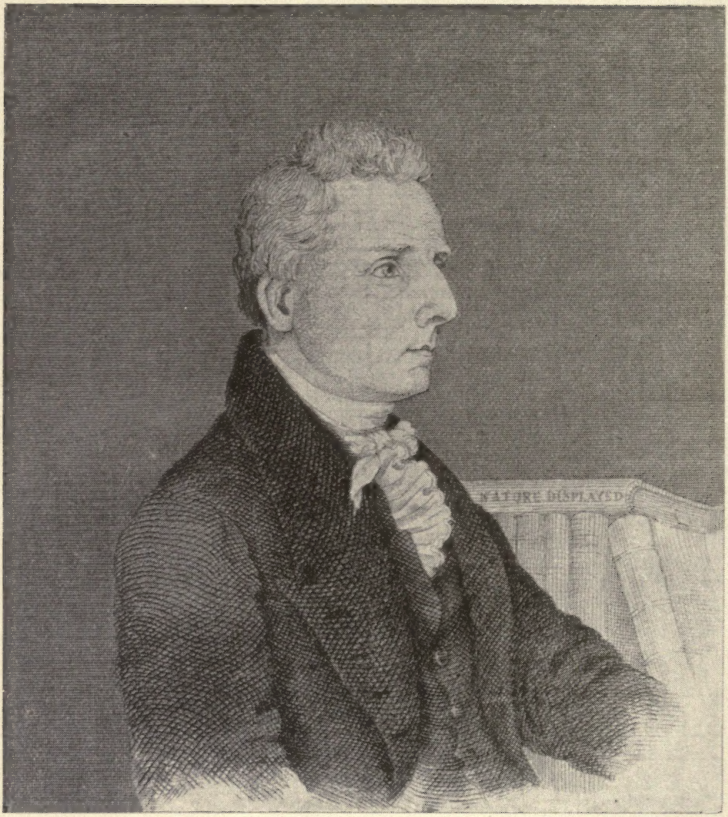

Simeon Shaw

THE

CHEMISTRY OF POTTERY,

&c., &c.

Φήμη γάρ τε κακὴ πέλεται, κουφη μεν ἀεῖραι
Ῥεια μαλ, αργαλέη δὲ φερεῖν, χαλεπὴ δ' ἀποθέδαι.—HESIOD.

Do this—yet shun ill fame—at first with ease
Borne, because light as air, but soon man finds
Its weight too great to bear, or yet shake off.

THE

CHEMISTRY

OF THE SEVERAL

NATURAL AND ARTIFICIAL

HETEROGENEOUS COMPOUNDS.

USED IN MANUFACTURING

PORCELAIN, GLASS AND POTTERY.

BY SIMEON SHAW, LL.D.

AUTHOR OF "NATURE DISPLAYED," &C., &C.

"QUID VERUM ATQUE UTILITAS, CURO ET ROGO, ET OMNIS IN HOC SUM; CONDO, ET COMPONO, QUÆ MOX DEPROMERE POSSIM."—HORACE.

"IN WHAT IS TRUE AND USEFUL, MY WHOLE CARE AND ENQUIRY, I AM SOLELY OCCUPIED, ALWAYS COLLECTING AND DISPOSING, SO THAT THE STORE CAN AT ANY TIME BE IMMEDIATELY DRAWN FORTH."

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GENERAL

"ENGLISHMEN—A RACE NOT SLOW AND DULL, BUT OF A QUICK, INGENIOUS, AND DISCERNING SPIRIT; ACUTE TO INVENT, SUBTLE AND SINEWY TO DISCOURSE; NOT BENEATH THE REACH OF ANY POINT, THE HIGHEST THAT HUMAN CAPACITY CAN SOAR TO. WHAT WANTS THERE TO SUCH A TOWARDLY AND PROLIFIC STOCK, BUT WISE AND FAITHFUL LABOURERS, TO MAKE A KNOWING PEOPLE, A NATION OF PROPHETS, OF SAGES, AND OF WORTHIES?"—MILTON.

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THE delightful idea I gratefully cherish, that your distinguished Patronage of this Volume results from the wish for Science to perfect the Manufactures of PORCELAIN, POTTERY AND GLASS.

Under your sanction, to equalise the information current, my Researches and Experiments are published, instead of being deposited with my children, and their usefulness diminished. The purpose is not to teach the *manipulations* of the Plastic Art. To persons *practically* acquainted therewith, to presume to supply written instructions and directions would be only to sacrifice time and labour; while to those ignorant thereof, scarcely can they be so clearly detailed as by them may be communicated or acquired the knowledge to reduce them successfully to practice.

The Bark bearing the *matéreil* of progressive advancement may be delayed by that indifference which declines or withholds the needful supply of stores; or be hindered or prevented by that timidity which imagines the voyage too inauspicious to be attempted; or for want of a pole-star for its direction, in presuming to breast the billows of the trackless main, may encounter the danger of being stranded by that

contumely which measures mental by pecuniary store; and it cannot, without some difficulty, be safely piloted into port: yet no sufficient reason has been assigned, that there should be longer delay in taking advantage of the current of scientific research, and the tide of general improvement to bring these Manufactures within the safe harbour of immutable certainty.

Dr. Priestly very pertinently remarks: "Those persons are deservedly disappointed who, for the sake of a little more reputation, delay publishing their discoveries till they are anticipated by others." But (except Fourcroy and Brongniart*) not one philosophical chemist

* "This distinguished cultivator of the Science of Potting is preparing a History of the Art of Pottery, and making great exertions for the formation, at Sèvres, of an extensive and instructive collection of everything relating to the Art. He has distributed a Circular, which is inserted in different Philosophical Journals, and is a useful model of such letters missive, as evidence of the comprehensive views of the collector, and of the relaxation of the French government with regard to the Customs' regulations in scientific importations. Both Art and Science have hourly to regret the obstructions and losses produced by the interference of the Custom-house officer.

"In a letter, dated March 8, 1836, addressed to the editor of *Silliman's Journal,* is this statement: 'I am much occupied with a work upon the history of the Plastic Art, or the Art of Pottery; and the requests which I take the liberty to annex, have for their object the enriching of a grand and instructive collection which I have formed at Sèvres, of everything relative to the Art of Pottery.'

of celebrity, continental or native, until Faraday stepped aside from his systematic studies of the characteristics of Atoms to investigate these arts ;

"*Royal Manufactory of Porcelain, and for Painting on Glass.*—*Sèvres, March* 8, 1836.

UNITED STATES OF AMERICA.

(*Circular.*)

"Instructions as to the manner of co-operating towards the completion of the Collection relative to the Arts connected with the Manufacture of Porcelain, and with vitrification, founded at the Royal Manufactory at Sèvres, near Paris :—

"1.—What kinds of pottery are used by the different classes of inhabitants of the country : the agriculturists, the mechanics, citizens and merchants, poor and rich ?

"Is the pottery of native or foreign manufacture ?

"If foreign, from what country does it come, and in what way ?

"If of native manufacture, where is it made ?

"2.—As to the NATIVE POTTERY (and under this name we include all varieties, from the most common to porcelain), it is desired to collect and procure specimens of every sort. Common pottery, both with and without glazing. Delftware common, and Delftware fine. Pottery of brown free-stone ; crucibles. Varieties of porcelain. Bricks, both common and those manufactured by particular processes.

"Plate species.—Plates, oval dishes.

"Hollow ware.—Cups, salad-dishes, tea and coffee-cups.

"Round pots, hollow-moulded.—Oval and square pieces, saucers, boxes, etc.

"The largest piece of each sort that is made.

"The name given in the country to each piece.

"The price of each upon the spot.

"Whether there is exportation, and to what place.

and by some interesting elucidation of the most general laws hitherto developed, or practical suggestion for improving the processes, be-

"3.—Fabrication.

"1. *Materials for the Mass, or Paste.* Clays. Marls, or Plastic Earths which may be substituted for them. Sands. Rocks on stones. Limestone.

"*For the Glaze, or Enamel.*—If stony materials—feldspar-stones.

"If Metallic matters—Metals, their oxides, and metallic glass.

"Exact localities from which these materials are drawn.

"2. *Modelling.*—Moulds of plaster, of terra cotta, or other materials, of whatever kind.

"The lathe and other instruments for fabrication.

"Sketches, with exact dimensions of these instruments, if it is supposed that they differ from those used in Europe.

"3. *Baking.*—Form of the ovens, sketched, with the dimensions.

"Combustibles used, indicating them in the clearest manner possible.

"4. Information peculiar to the country.

"1. To designate the principal Manufactures of Pottery, Glass and Porcelain, in your vicinity.

"2. Whether there is in North America ancient pottery; that is to say, pottery fabricated in remote ages, and which has not been made for a long time. This pottery is found, in general, in alluvial soil, in the ruins of towns, and perhaps, as in some parts of Italy, of South America, and of the oriental countries of the ancient world, in the graves or tumuli. In Europe, these things have often been admitted into Museums as monuments of antiquity, but almost never as in relation to the Art of Pottery and its history. It is in this latter point of view that I regard them, and that I have collected a great number of the ancient pieces of pottery in the Museum at Sèvres.

"To endeavour to collect some pieces of this antique pottery, and to indicate exactly the place and the circumstances in which

stowed on it some permanent mark of his casual notice.

Philosophy claims to direct the most elaborate and minute manipulations of British

they have been found, and to endeavour to decide whether it had anciently any celebrity, always however mistrusting the deception of the sellers.

"3. Whether there is knowledge from traditions, inscriptions, etc., that the natives (aborigines) of North America have ever fabricated or known glass.

"*General Instructions in Relation to the Purchase, Packing and Forwarding of the Objects collected.*

"The expenses which may be incurred in procuring the Specimens and the Information will be reimbursed by the Administration of the Royal Manufactory at Sèvres, upon a reference to the person who shall be designated to receive the amount.

"It is expected that these expenses will not rise to a great amount: it is requested, in any event, that they may not exceed in any one year the sum granted, *i.e.*, 200 francs for 1836 (£8); 200 for 1837; at least, without a previous understanding with the Administrator of the Royal Manufactory at Sèvres.

"It will be necessary to pack the pieces with great care, and to consign them to a merchant in one of the ports of France, to be forwarded by way of slow transportation to the Administrator of the Royal Manufactory at Sèvres, forwarding also the expenses of transportation.

"It will be necessary that the correspondent at the seaport should write a letter of advice to the Administrator of the Royal Manufactory at Sèvres, near Paris, before the forwarding, in order that the latter may obtain from the Director-General of the Customs permission for the box to pass under seal (*sous plomb*), and not be opened until it arrive at Paris: this is very important, to the end that there may be no derangement of labels, nor any breakage. It is equally important that the tickets which may

MANUFACTURES. Their close investigation clearly elucidates the successive improvements consequent on the artisan's progress in understanding, mental cultivation, correct reasoning, approaches towards perfection in the Arts of Life, and success in supplying ascertained

indicate the places where the pieces were made, or those from which they come, should not be separated and mixed during the unpacking. It is desired, therefore, that they may be fastened either with glue, or with good wafers, or with twine.

"Lastly, it is very desirable that there should be attached to the case a separate box, either of lead or of tin, and that there should be sent separately notes previously made of the objects collected and forwarded, taking care that a correspondence be established between the objects and notes by means of a series of numbers, etc.

"ALEXANDER BRONGNIART."

Magazine of Popular Science, No. XIII., pp. 66, 67.

In pages 374 and 415 of this Work, I have mentioned the *Burslem Museum* for the Illustration of the Art of Pottery in Staffordshire, the private property of Enoch Wood, Fountain Manufactory. But I feel it a duty to express my opinion, that except M. Brongniart, no person has taken so much delight in traversing the wide range of this vast and diversified field. The latter gentleman, surpassing many in vigour of understanding and capacity for profound research, alike eminent for the variety and versatility of talent, and meritorious for zealous, unwearied, and productive employment, in devoting to this object (which I am satisfied is both instructive and entertaining) a large portion of his attention, he only fulfils what he conscientiously regards an important part of his duty to his country, to posterity, and to the Manufacture he has so greatly advanced.

deficiencies; and most interesting is their explanation by a lucid exhibition and skilful arrangement. Many of these Manufactures have the invaluable *auxilium* of a Society specially adapted to collect the series of facts which explain those modifications of arrangement whence have originated the successive improvements; to promote mutual intercourse and comparison of information, while stimulating essays at excellence among the members generally; to excite and appropriate the sedulous co-operation of individual researchers in the utmost possible expansion of the intellect —the most interesting *desideratum* in each person; and, with resistless potency, to involve in its circuit those minds desirous of distinction, athirst for reputation, or charmed with participating the effulgence of truth. But,

In reference to the Potter's Art, perplexity and incertitude have generally predominated. Little comparison of theory with experiment, and its immediate consequences, has been attempted; neither has the public mind been excited by reducing complicated results to simple laws, or exhibiting the need of others, new and supplementary, or connecting the general bearing of the important truths eliminated in the progress of discovery, established

by independent facts and observations, and generalised by the determined connection of parts. Selfishness, which always is short-sighted, has hitherto governed its destinies; and disastrous has been its sway, alike to its own interests and those of the community. By wholly precluding, or delaying to a future time, the general diffusion, the full and clear detail, of that affluence of new facts, involving the characteristics of the materials of the numerous compounds, almost simultaneously observed by several persons, and rapidly accumulated during the latter half of the eighteenth century by Booth, Whieldon, Bird, Yates, Baddeley, Chatterley, Palmer, Warburton and Wedgwood!—there have not been presented opportunities for deducing tentative approximations for future experience to confirm or correct, circumscribe or enlarge; or, for successful examination, with resolute and rigid precision, of their ultimate composition, so as to ensure their perfection by fixing it on a solid basis of combination developed by the employment of definite and multiple proportions of components. The detached facts, since that period, belonging to the Art, certainly are very numerous; but, alike in the full records of individual statements, and in those

where the mere formulæ indicate the results, and careful estimate made of the arithmetical mean, only few have been applied practically to elucidate any one theoretical difficulty in the Art; or to supply the elements for the construction of some definite General Laws to connect phenomena, when carefully compared with similar deductions already recorded. Neither has any advantage resulted from the details in the cyclopædias of Rees, Napier, Curtis and Lardner, which profess to supply a clear view of the processes and manipulations of the Art. The sanction of a diploma, the magic of a name, prevent determination of the real amount of sterling information supplied, and secure currency to assertions unsupported by facts or arguments, or to defective and incorrect remarks. From these trammels I had to extricate myself properly to estimate the weight of authority, and verify the occasional conclusions, that I might avail myself of whatever was adapted to my purpose; and very trifling, indeed, is the sum of what I regard as accurate, when compared with the mass presented to the reader; the mere statements of traditional dogmas.

I scarcely need advert to the unavoidable and unconquerable difficulties which rise to

obstruct the progress of those practical men whose knowledge has only personal experience without any theory; whose rules are mere happy contrivances, accidentally invented, and found to answer their special purpose; and who see only a series of isolated processes, distinct from any common principle; while they who regard only theory, see a collection of abstract propositions, associated and beautiful mentally, yet without practically affecting the necessities and Arts of highly-civilised life. Both of the parties admit the importance of Chemistry in the Manufactory, as well as in philosophical science; yet of its details and capabilities, competent and really useful knowledge is possessed by few among the votaries; and in the works mentioned, there is no supply of the kind of information adapted to their daily wants.

The expectation seems reasonable, from the advanced state and increasing rapid strides of Scientific Chemistry, and the light supplied by those new and interesting doctrines which recent researches have raised to an eminent position, and because most to these Manufactures can the researches and discoveries supply useful and important information, that thence will arise valuable suggestions for systematic

improvement ; that their investigation will attract the energies of every one who feels within himself the vocation of discovery ; that the bright promise of future advancement will engage the attention of both the inquiring and the indifferent ; and, that, even in those who have most adequate knowledge of the nature of the acquisitions possible, and the probabilities of further additions, there will be excited a feeling of scientific exultation and gratulation. The more numerous the discoveries of Chemistry, the more distinctly will be observed the avenues for additional supplies. The increasing demand for these, or for improved combinations, incontestably proves the progress of correct information, and the extension of accurate scientific knowledge. The better the Manufacturer comprehends the nature of these discoveries, because of the exhibition of the results in the form supposed best adapted for the purpose, the more clearly he sees that these useful Arts of Life have not for their basis and object only a practical intimacy with the mixing of materials, and vague knowledge of products in the wares ; heterogeneous groups of facts, of little avail in efficiently promoting any one branch of the Arts, or concerning it to afford precise information ; yet, when care-

fully investigated severally in connection with others of the like character, supplying the most valuable aid to scientific generalisation—the more is formed an experimental acquaintance with the condition of the different materials, which, after fritting, or baking of biscuit, constitute excellence of productions—the probability will the more readily be admitted, that future researches will suggest methods of improvement ; but, for which, the opportunity will be lost, unless the discoveries be carefully registered, and the results be compared numerically, with special regard that the properties associated with the numbers in the different cases are clearly and precisely the same. By some persons they may be considered as isolated facts ; but others, who pursue philosophical inquiries, will find the generality of them connected with useful conclusions, tending to further elucidate these truly advantageous branches of National Industry.

That many attempts have failed, though made by persons whose experience might be supposed a guarantee for success, I readily acknowledge ; also, that many essays, which in the closet or laboratory promised advantages, could not be brought on a large scale into practical operation ; yet these very failures

should not dishearten the parties, but lead them forward to correct results, to accurate knowledge, and thus slowly and surely pave the way to certainty and success. On attentively examining the products of the Plastic Art at the commencement of the present century, there is cause of gratulation at the progress since that period, more than in all previous, made in the several departments, in the consideration and extension of theory and the practical application, in the improvement of mechanical processes and facile manipulations, in the willingness to suggest or communicate improvements, in the additional number of those who are interested in promoting the excellence of these products; and there may be confident anticipation that the next twenty years will be distinguished for much greater proportionate advancement of this compact of genius and industry, become so indispensable to the conveniences, and comforts, and general usages of civilised life among all nations.

The general Arrangement of the respective Subjects, in the several Parts and Chapters, will be understood from the *Table of Contents;* while ready reference to the numerous notices of Particulars is supplied by a copious *Index.*

The First Part presents Chemistry as a refined Science, whose numerous votaries regard solely how most effectually can be accomplished the progressive increase of their control over the imitations of Nature's productions, as well as the extension of their dominion over herself. In developing important relations of all substances discovered in all countries, Chemistry now promulgates Facts in the universal language of experiment. To exhibit and classify many relative to the Arts of Potting and Glass Making—interesting and important, because their ascertained and correct results are adapted to supersede the labour and anxiety of uncertain essays—is my sole purpose—not "the most ingenious way (according to Dr. Hooper) of becoming foolish, by [promulgating] a *system* [of notions and schemes]; as the surest way to prevent Truth, is, to set up something in its room." But, in a manly tone, and with high sober diction, and, where proper, the immutable precision of arithmetic, are presented the reasonings and researches at this day current, of the numerous examiners of the yet more numerous particulars; free from the customary indecisive common-place phraseology, also the unphilosophical though brilliant and poetical terms—*affinities*, *elec-*

tions, *attractions*, *repulsions*, *preferences*, *aversions*, and similar occult words.

Many are the interesting theoretical inquiries concerning the manner in which the elements exert combinative potencies transitive and receptive, in forming compounds, and these latter again in the formation of substances, natural and artificial. Little could be expected in elucidation of this remarkable fact from the dissimilar and not seldom conflicting conclusions of different former analysts, and which were only tolerable approximations relative to one and the same subject, and not determinations whose accuracy is admitted as entitled to confidence. But the assiduous researches of the most expert recent analysts—while engaged in the most skilful and delicate experiments, and numerous syntheses consequent on the operose analyses of substances by processes the most improved, and whose accuracy precluded disputes concerning the components and proportions—have supplied many probabilities, that it presents a series of multiples of a common force (as stated, pages 35-62), whose clear development and full comprehension only can supply ability to precisely determine their limits of error; like as the atomic weights of the elements themselves, from other facts, are

regarded as multiples by a whole number of a common weight—that of hydrogen.

The mathematical elucidations introduced I regard as alike pertinent and indispensable ; and not because less toilsome than experiment, neither as the subterfuge of human pride to evade the concession of human imperfection. When our "knowledge of the chemical and physical properties of bodies which surround us, as well as our imperfect acquaintance with the mysterious modification or change of their combinations, concur to convince us of the same fact, we must remember, that another and a higher science itself, yet more boundless, is also advancing with a giant's stride, and supplying expressions, which are to the past as history, and to the future as prophecy ; it is preparing its fetters for the minutest atoms in nature, it becomes continually the more necessary at every step of our progress, and it must ultimately govern all the applications of science to the Arts of Life, the Science of Calculation."—BABBAGE.

Here it may be proper to mention that, while employing ingenious investigations, original experiments, and tentative calculations for the better development and further extension of these particulars, I noticed the

PRINCIPLE which is detailed (pages 46-49). It seemed too important to be hastily adopted from a few casual observations ; and its application—to many compounds whose components combine by virtue of the opposite equilibria of combinative potency, also to others, productions of nature, which have been subjected to the most scrupulous and ingenious analysis —and the verification thence obtained, were most carefully examined ; and, reasoning that what occurs in these instances will very probably ensue in many others, I have ventured to record it, though the effect which it has on my mind may differ from what it has on the minds of those whose contracted capacities lead them, when judging of great discoveries after they have been made, and of which the simplicity excites their surprise, and the supposition, often censoriously promulgated, that little difficulty was involved in apprehending the subject.

Wishful to help the Manufacturer to obtain adequate ideas, and full and clear comprehension of the properties and composition of the various MATERIALS he receives, and to enable him to ensure most advantage from what are good, and secure himself from that cupidity which supplies deteriorated sub-

stances, in addition to mention of apparatus, I have fully detailed ready and correct methods of *Analysis, General and Particular*, and the investigation of the peculiar state of equilibrium of combinative potency in the respective components of the inorganic ingredients used in forming the *Artificial Silicates*—Bodies, Glazes, Glasses, Colours, etc., and to verify the researches of persons, *synthetically* in compounding these, and *analytically* in separating their various components. The path may appear long to some, who wish solely to regard practical investigations ; but those who desire to have the full advantages of order and of generalisation, will follow its windings attentively ; and any new views which may thereby be enjoyed, will interest mostly the philosophical inquirer. When the mind, calm with experience, by the rays of the lamp of science investigates and discriminates the characteristics of substances, they clearly appear, as useful or valueless, adventitious ingredients mechanically mixed, or essential and chemical components, and a compound of different elements, or of varied proportions of the like elements. The hope is indulged, that with these methods, and the principle above noticed, to guide future combinations, gradually will

diminish the present prevalent obscurity and confusion ; and, by the practical knowledge of which are in all cases real proximate principles, as well as which are incompatible ingredients, seldom will be employed a compound, destructible by the usual alternations of temperature ; but all will be regular, so that with accuracy each production of the laboratory may have its proper place assigned it in a chemical arrangement. I therefore press on the young Manufacturer assiduous attention to the details in the First Part.

The SECOND PART contains numerous original, and I trust, valuable observations. There appeared propriety in commencing with *the Progress of the Manufacture of Pottery*, from earliest times, from incidental allusions, or explicit mention, by historians and travellers. Where conflicting testimony left the subject questionable, I have attempted to decide.*

With reference to the SCIENCE OF MIXING, the Fabrication of excellent Wares, and Compounding of Bodies, Glazes and Colours, involve the necessity for the component particles to be by some means brought into due and almost mathematical juxtaposition ; and this

* On the history of Glass-Making, I must refer the reader to Mr. Cooper's *Glass Manual.—London,* 1835.

only can be accomplished by the aid of the mill, with which, in the opinion of persons of adequate experience, the most careful manual mixing will never compare. The Manufacturer's success is involved in the economical and scientific determination of the precise *quantities* of Components of Body, Frit, and Glaze ; yet dependence is placed on the *Guesses* (only occasionally correct) of the *Mixers*, and the slip-maker's judgment of the semi-fluid in the slip-tank. The first opinions and predilections (however absurd) of practical men, being entertained and cherished as First Principles, not to be rejected or questioned, must be admitted as a chief obstacle to improvement. But others, equally insuperable, have a very different origin : persons enjoying opulence and rank remain indifferent to the processes, or entirely ignorant of the principles, whose development, either more or less remote, has been the prolific source of their elevation.

In 1823 great expectations were entertained that the Scientific Improvement of the Plastic Art would follow the posthumous publication of the *Recipes and Processes* of Mr. Thomas Lakin, during many years the manager of a large establishment, which presented unusual opportunities for the develop-

ment and appropriation of talent in these manufactures. It was conjectured that his memorabilia would present the subjects that had occupied his chief attention; and that with the prophetic sagacity of a powerful mind, he would anticipate the Art's future progress, and develop the processes that would promote most effectually their successful advancement. But as the published *formulæ* did not bring down to that day even the knowledge then current, every purchaser has expressed disappointment. Had Mr. Lakin possessed the ability and inclination for improvement of the Art, and instead of observing all the ordinary methods, perhaps not the most ready or useful, and at hours merely in accordance with convenience, or by accident—had he directed his attention even to the merely mechanical examination of any one phenomenon, not to the mixed result of a chaos of heterogeneous principles—had he with scrupulous minuteness determined the specific gravity of each kind of ware, and registered the scarcely suspected variations thereof resulting from varied proportions—had he directed his investigations to the detection of the proximate causes and efficient remedies of crazing—had he reiterated experiments, under each possible condition, to solve the beautiful problems of the best Body,

and Glaze, and Colour in each series—had he taken advantage of the important situations he often occupied to carefully study the influence of humidity upon the earths, alone or mixed together, and of varied temperature on their amalgamated masses, or on the compounds of earths and alkali—had he in these, or in other equally interesting and fertile paths of inquiry, added to the current amount of knowledge of the connection of cause and effect in these peculiar and intricate as well as interesting and important Manufactures—he would have conferred, at, perhaps, less expense of time and labour, and certainly of personal credit, an infinitely greater boon upon the Art he professed to promote, than by recording the *formulæ* posthumously published by his family.

But in vain do we seek therein for facts elicited by the progress of experimental science; or exposition and elucidation of the reciprocal potencies of materials; or explanation of the causes, and exhibition of the ready and efficient remedies, of the disastrous failures frequently occurring. The omission, whether from incapacity, or neglect, or disinclination, involves in disrespect the memory of Lakin. Yet I think the fault really can be found in the *mystification* adopted by these cherished opinions, as well as

by those of his predecessors. As far as any proofs have been published, even Wedgwood, whose celebrity has been circulated throughout Europe, does not appear to have had definite and clear ideas of the Chemistry of Pottery, or to have entertained just notions of the true nature of Chemical Combination; for there is great probability that he suffered himself to be misled by vague and groundless hypotheses on the cause of the adhesion of ingredients in the Bodies, Glazes and Colours of the Wares, as though the particles respectively were wedged so closely together, that separation became next to impossible. Although proved to be hypothetical, and not countenanced by either sound reasoning or fact, his statements relative to his pyrometer were admitted without proof, and for some time regarded as the true measure of the potency with which heat solicits solid substances. But, for examining with great sagacity the current manipulations, for laying the foundation of the practice of best workmanship, by establishing the means whereby at that time could be secured and determined its relative goodness, his merit is indisputable, and justly entitled to the gratitude of posterity. After any deductions from his merits, which may justly be made because he did not produce Porcelain and Ornamented Printed Wares,

he must be allowed to occupy the highest place among those of our countrymen who have advanced the Plastic Art to its present rank. Little did contemporary Manufacturers wish to award the great amount of credit due to the party who at once perceived the value of a casual observation, or of an unexpected result; who discriminated which facts are trivial, and which are important; and selected the latter to guide him through difficult and perplexed mazes of investigation.

A few persons, of whose liberal views a high opinion was entertained, have expressed fears that the publication of this Volume will injure the Trade of the Districts also, and the Manufactures, by divulging the *Formulæ* for compounding Bodies, Glazes, Glasses and Colours, supplying much valuable information to foreigners heretofore unattainable; and yet these persons do not blame the cyclopædists for publishing very minute analyses of the processes, and an elaborate description of the machines employed and current in every Manufactory. Knowledge, industry, and integrity, are the only secrets of trade which ever ensure respect and wealth, and to whose possessors the exposure cannot be injurious. Individual and general advantage result from appropriating light from all quarters, and causing it by reflection to irradiate the

surrounding area. And, as knowledge is available precisely in proportion to the respective capabilities of the persons acquiring it, every invention or improvement relative to these Arts will be primarly attracted to the Boroughs of Stoke-upon-Trent, Birmingham and Dudley, as the most productive scenes of development, where it can most profit the inventor, because most profitable to the Manufactures there established. Whereas, mystifiers, who betray a jealousy of competition, often are vain persons, guilty of the silly blunder of estimating their own intrinsic resources above those of all the world besides; some ingenious neighbour has supplied a few hints, upon which they work in secret, and outmanœuvre themselves by trying to steal in the dark a march upon their friends, excluding every observer, and in turn becoming insulated and excluded, absence of external illumination promotes their adumbration, till a few years of exclusiveness places them in the market, with inferior goods and higher prices, yet deprived of their oldest and best customers.

The advancement of the Manufactures will be most efficiently promoted by the skilful potter and glass-maker knowing the treasured-up recipes—*secret* and *invaluable!*—affording, in the simplest form, the supplementary traditional information of many now vanishing

from actual practice, unexpectedly extending the views of the various combinations once prevalent, often supplying links(otherwise absent) to unite the numerous subjects in a continuous and unbroken chain, and also, means of reference for ascertaining the steps by which were acquired the results. However much some of those of the Plastic Art approximate to others practised by predecessors abroad, or contemporaries at home, yet, as the extraordinary productions of native and uneducated sagacity of intellect, they challenge warmer admiration, and the merit of originality; and, of their qualities, because of changes in components or proportions, ignorance is not desirable any more than is inability to comprehend combinative potency and recipience. By such a method of comparison, the aggregate of the respective components of each *kind* of product generally presents an assemblage almost identical and their subordinate distribution is chiefly affected by their diverse chemical composition. Nature is, doubtless, the Manufacturer's best director; and yet, by means seemingly most simple, she obtains the most grand and correct results. To present the scientific experimenter with opportunity for a close and severe scrutiny of the series of means employed to imitate these results, is to bring within probability suggestions and

additions whose importance and value are not easily calculated and determined. On this account, kept in the privacy of the Manufacturer's office, or mixing room, each recipe is little more than a mere appendage, as completely unconnected with the promotion of scientific improvement as are specimens of Natural History exhibited in itinerant museums.

The *Formulæ* are presented in *centessimal* proportions, the more easily to ensure accuracy in compounding each, also excellence of results in accordance with the combinative potencies of the compotent materials. It is expected that the defects or errors which may arise will be easily understood, and the proper remedies also, by him who can comprehend and usefully apply the calculations introduced, and repeat the experiments for assigning with confidence the proportionate components for each respective compound. CRAZING is a problem whose accurate solving is of the highest interest; and I cannot think otherwise than that the time is approaching when the attempts to entirely prevent it will be completely successful, and also much more common than can now be admitted. For this desirable object, seemingly we must be content to proceed gradually, availing ourselves of the researches of celebrated experimenters, and the advanced state of Che-

mistry. To gradually diminish uncertainty on this subject, I have stated from careful experiment and sound theory different suggestions; even although the value of some may be less than the errors of remark, or the unavoidable incertitude consequent on the presence of imperfectly understood active causes. And, admitting that there may be a limit beyond which human perseverance cannot carry the approximation to truth, and one, much wider, within which some of the many trials made will not possibly come, yet by such means as are here mentioned will uncertainty progressively diminish, will truth be separated from error, and will be eliminated with precision the actual anomalies already brought under consideration.

The Manufactures will continue without a solid basis, or the true dignity of a science; and will abound in empirical rules and inconsequential reasonings, until fully are comprehended the PROPERTIES OF HEAT, concerning whose vast importance in the economy of nature and in these (and probably all other) Manufactures, very imperfect and crude notions are entertained by potters especially. Each of the several components of Bodies, Glazes, Glasses and Colours, has peculiar relations, which pay varied and varying behaviour to its action in the extremely high temperature of the potter's

oven ; and which require to be clearly ascertained, "*et ignem regunt numeri.*"—FOURIER. The clear recognition of the Laws which regulate its general distribution and propagation in solid substances, forms the first, the most important, yet profoundly difficult problem in the theory, to be solved ; and it is one of the most interesting investigations of the Arts, because of being essential to all accurate knowledge of the Causes of the Combination of Earths, every department of which is subject to its potency. However great may be the difficulties, yet as accurate means have been adopted to elucidate and determine many of them, the hope is entertained that only of very short duration will be the present prevalent ignorance.

The THIRD PART comprises TABLES *of the Characteristics of Substances*, on which is firmly based the more exact Chemistry of the present day. These have been investigated by different persons with minute and rigid precision ; and of the utility of presenting them, in extent and arrangement, different and superior to all I have had opportunity to examine, I anticipate the approbation of every adequate judge.

Some persons have occasionally suggested that future generations will minutely investigate the reasonings and observations herein promulgated, and will give an opinion on their

relevance to the subject, as well as on their merits, at a day when will be well known the particulars of which I have treated. I shall be excused the vanity of believing this. I have intentionally delayed the completion of the Work that I might the better fulfil my obligations to the Subscribers, and the duty I owe to the Manufacturers generally; not that I am either required or expected to penetrate into the progress of the Art beyond the possibility of improvement. And, having collected and preserved most of the important Facts now current, also endeavoured to supply useful information heretofore unpublished, and to excel in what had never been previously attempted, I am fearless of any criticism; because, for it to be pertinent, it must further promote the Object I most desire—the Advancement of these Arts to unparalleled excellence.

Of the necessity for all possible Improvement of these Manufactures no doubt can be entertained. The most fixed principles of human nature, the examples of all history, prove the fact that should foreign rivalry ever be successful, it will do little less than utterly extinguish these staple Trades; whose present elevation will be the exact measure of their depression, because precisely that of the jealousies and excitements of the rivals, who will

continue fearful of being surpassed, and never rest certain of pre-eminence while there remain the smallest vestiges of manual expertness, or specimens that talent has existed and been encouraged, or artisans excited by adequate remuneration, and, until our ingenuity lies torpid, our commerce destroyed, our wealth dissipated, and our independence overthrown.

Whatever attention may be due to the previous remarks, I would appeal to sentiments more elevated. An adequate idea of the importance of Progessive Improvement requires the mind to be raised to a suitable level, that the views may contemplate a distant futurity, and consequences the most certain, however remote. As far as concerns the interests of the Manufactures, YOU, MY PATRONS, are, in fact, the Federal Representatives of British Potters and Glass Makers. You must determine how shall be effected the latest Improvements; their commencement is entrusted to you; and on you depends the excellence of subsequent productions. If Invention, after lying torpid on the coasts of Italy, be desuetude in Staffordshire, where shall it ever emerge from the darkness in which the Arts will be involved? You, then, must decide, whether that Genius, at whose voice Germany, and France, and Britain, awoke from the sleep of ages, to contest

the career of excellence in the useful and the ornamental; and by whose magic touch the crude supplies of nature are converted into Articles, to embellish life with conveniences for use or luxury; that Genius, which has poured wealth into the laps of its votaries, shall be cherished, and protected, and encouraged; or be invested in a funeral pall, and wrapt in eternal gloom. I anticipate your decision. The Patronage afforded me manifests your solicitude to approve yourselves worthy of the dignified trust; and the difficulties which will have to be surmounted, the arrangements which must be made, and the essays to be accomplished, are not to be mentioned in comparison with your anxiousness to mingle in the strife for perfecting the Manufactures.

One favour more I most urgently yet respectfully solicit: To preclude from obtaining Information at your expense, persons who were unwilling to patronise the publication of this Volume; do you resolutely disregard every importunity by persons not in the List prefixed, for its *loan*, or *perusal*, until the expiration of twelve months after its delivery.

I remain, with unfeigned gratitude,

Your obliged, humble Servant,

SIMEON SHAW.

Tunstall, July, 1837.

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CORRIGENDA.

On page 517 of the present issue Chapter III. appears. This is a misprint which appeared in the original. As the contents indicate, it is Chapter V.

ADDENDA *to Page* 251.

The following Remarks were supplied on the 28th of June, 1837, by an esteemed Friend:—

"A pint of slop-flint should weigh 32 oz., and a pint of water weighs 20 oz.—the difference is 12 oz.—so that if the pint be 12 oz. deficient, or short of 32, then clearly it is entirely without flint in it, and is all water; and the total deficiency in the tub of flint will be 40 pecks.

Agreeably to this method of determination, the rule for ascertaining the deficiency in a tub of 40 pecks, by the weight in the pint, will be:—

As 12 : are to 40, : : so are the ounces deficient in the pint, : to the pecks deficient in the tub.

Problem.—What is the deficiency in the tub of flint when the pint weighs only 29 oz.?

Here the pint is 3 oz. short, therefore:—

12 : 40 : : 3

3

12 | 120

Answer ..... 10 pecks.

So that when the pint weighs only 29 oz., there will be only 30 pecks of flint in the tub of a proper weight or liquidity; and the other ten pecks *are water only*, which may be easily accounted for by the following reasoning:—

The deficiency of 1 oz. in the pint equals a pound in a peck, or 40 lbs. in the tub. Then, in the preceding example, the tub will be deficient in weight 120 lbs., and will weigh only 1,160 lbs. instead of 1,280 lbs. Now,

30 Pecks of flint weigh 960 lbs.

And 10 Pecks of water weigh 200

1,160

Proving the accuracy of the former result.

A pint of flint, when carefully evaporated dry, will weigh $18\frac{1}{2}$ oz.; therefore, when *slop* flint is charged *sixpence* per peck, *dry* flint is worth £3 1*s.* $4\frac{1}{2}$*d.* per ton, when perfectly dry, besides the expense of drying.

A pint of grauen (china stone) when evaporated perfectly dry, will weigh $17\frac{1}{4}$ oz. Therefore, when slop-stone is charged sixpence per peck, dry stone is worth £3 4*s.* 11*d.* per ton, when perfectly dry, besides the expense of drying."

G. B.

ADDENDA *to Page* 492.

Boracic Acid has potency over lime exceeding any other flux; and hence the employment of borate of lead is useful in the manufacture of glass that has lime present in the pot.

Boracic Acid, in the heat of the potter's oven, communicates to flint an orange, and to grauen a primrose tint, with intumescent mass, but smooth surface. Soda improves the natural tint of both, with a bluish radiance of the latter.

Problem.—What proportions, fusible at 86° Wedg. 12,000 F. will produce an homogeneous white transparent glass, indifferent to atmospheric action?

Boracic Acid improves the colour of bone earth, and yet injures that of china clay; soda improves the colour of the clay, yet injures that of the bone earth.

Problem.—What are the proportions which will most usefully combine in a glaze that will not craze?

G. B.

THE

CHEMISTRY OF POTTERY.

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PART THE FIRST.

ANALYSIS AND MATERIALS.

"The efficacy of Ignorance has long been tried, and has not produced the consequences expected ;—let KNOWLEDGE take its turn."—DR. JOHNSON.

CHAPTER I.

INTRODUCTION.

THE ARTS OF LIFE supply instances of periods when the Genius of Invention has been scarcely manifested; and others, when its progress has had accelerated velocity; among which latter the present seems most interesting, because of the amazing variety and extent of improvements presented to the eye of the intelligent observer.

Some natural wants—first supplied by the person in need, and others created by the requirements of civilisation—prompted the spirit of invention, the exercise of dexterous skill, and the subdivision of labour, which distinguish commercial nations. Thus commenced the several trades and professions, whose votaries and adepts only first practised them as mysteries, and by limiting the knowledge attempted

to monopolise dexterity in the processes and manipulations.

Society, however, claims every person's endeavours to promote improvements in these Arts; and the attempts to accomplish these are usually attended by a degree of remuneration in capacitating the person the better to fulfil the duties of the station occupied in society, and proportionately gratifying that resistless desire for knowledge inseparable from man's nature and condition. The advantages are much greater when liberal-minded men unite to extend information, explore and clear the path for pursuing Science, in the divulging, comparing, and illustrating of ideas, and render useful to all the successful labours of men of science, who, with much erudition, unite that talent, and judgment, and application which distinguished sages of other days, who have attempted to recommend themselves to society by an original cast of thinking, and have secured the perpetual extension of current knowledge, the effulgent rays of the light of science, and the invaluable capability of unlimited improvement, so that no earthly power can limit the number of those who traverse the path, nor determine the importance of the improvements, and the sum of their additions to the stock of general information.

The details most general of the Arts of Life, of extensive import in their applications, and powerful influence in our manufactures, are those of CHEMISTRY—one of the most useful, instructive, and curious of all mental pursuits. This is the science which develops the distinctive characters, peculiar qualities, and combinative potencies of elementary

atoms, and the reciprocal action and reaction of the components of substances. When engaged in its processes, the mental powers are delightfully busied in scrutinising the nature and behaviour of the elements employed, the union and usefulness, the essential differences of the resulting products.

This science assumed its modern importance in the hands of Beccher and Stahl, of Mentz; and during the last sixty years it has conferred great celebrity on many self-taught men, because of their discoveries how society, in conventional language, may comprehend why the unnumbered substances presented to the perception are essentially as different in properties, as varied in components, and have a certain and never any other manner of existence. Still, so varied are the subtleties of Nature that a rich harvest is now ripening, to be reaped by the master-minds of this century. Will it be presumption to hope that the diffusion of the knowledge of this day current—how, in accordance with certain principles, substances either combine or separate, and produce results—may awaken the genius of some other Priestley, or Davy, or Dalton, and secure a just appreciation of true talent and perseverance?

The thirst for distinction and wealth, so prevalent among mankind, strengthens the love of liberty, kindles the lamp of invention, and excites to almost every improvement in each of the Arts of Life. Every great and useful discovery has thus resulted, not from chance, but general laws governing the circumstances, and proving that the laws of nature are not more permanent and immutable than the progress of society is certain. This thirst excited that

beneficent addition to the stock of knowledge made by the alchemists—fools in the estimation of some, in the present day wise only to amass wealth; but, in reality, a race of steady inquirers, of superior powers of intellect, employing constant reasonings on every process. Every substance, even most offensive, they examined in their search after that chimera, the philosopher's stone; and this thirst produced acquaintance with the chemical properties of many substances, towards which the repugnance is so great, that scrupulously would they have been avoided only for this very powerful motive. Unwilling to seek an object in the dark, or blunder on it unexpectedly, they carefully pursued each glimpse of light along every intricacy of the labyrinth it traversed; and frequently in the ascertained characters of their agents, seeking directors for future processes, they remarked some peculiarity, available for one purpose, yet suggesting another. During more than six hundred years their processes—*Alchemy* in its disprobative force, the present approved Chemistry—formed an authorised science; and its votaries and adepts, the Christian priesthood (also the physicians and apothecaries administering to the physical and mental maladies of their flocks), only practised their chemical researches in secret, after the peculiar results were indeed so very wonderful to the uninformed as to be supposed accomplished by infernal agency, and proving the operator's compact with the prince of darkness. Untutored minds, aware that every effect has a cause, regard as a necessary conviction the philosophical sequence, suppose the changes in substances—violent, irregular, anomalous and

unaccountable—proofs of particular agency. Such ignorant and credulous minds, in this day, are imposed on by their successors, Charlatans and Quacks; but in former days the most sagacious and intelligent persons were imposed on, or astonished. And, when mere parade of eccentricity was substituted for knowledge, the more obscure were the parties' perceptions of the phenomena of their experiments, the more symbolical and figurative became their language, the better to conceal their pretended secrets from the uninitiated and the ignorant.*

One of this notorious fraternity, De Bötscher (of whom, hereafter, I shall speak more in detail), at the commencement of the 18th century, developed the *transmutation of Rocks* into the hitherto-unrivalled Dresden Porcelain—more valuable to his country than could have been the discovery of the philosopher's stone. And our day has been distinguished by the efficient processes of the greatest alchemist on the page of history, distinguished by Napoleon's epithet, as "the philosopher of England,"—Davy. Not content with the metals for his purposes of

* The following specimen is modest, compared with some extant: "Ye wretched and pitiful medicasters, who full of deceit breathe I know not what Thrasonick brags; infamous men, more mad than Bacchanalian fools, who will neither learn, nor dirty your hands with coals; you titular doctors, who write long scrolls of receipts; you apothecaries, who with your decoctions fill pots no less than those in princes' courts, in which meat is boiled for some hundreds of men;—you, I say, who have hitherto been blind suffer a collyrium to be poured into your eyes, and permit me to anoint them with balsam, that this ignorance may fall from your sight, and that you may behold truth as in a clear glass."—
Basil Valentine.

transmutation, he laid violent hands on the *mere Earths* (till that moment in their peculiar characteristics imperfectly known), he separated them from every extrinsic adherent, subjected them to the energies of the galvanic circuit, watched their behaviour when thereby solicited, and enjoyed the high gratification of receiving from the respective substances their elementary bases, as METALS. To him contemporaries of various nations have awarded the meed of acclamation; and his name will be remembered while science preserves her records.

The alchemists would have discarded the indifference or indolence so long prevalent in the manufacturers of the Wares from the Heterogeneous Compounds supplied by Nature and Art. They would have sought to be skilful *adepts*—scientific fabricators of Porcelain and Pottery, products useful and interesting in the economy of the nation; and by ceaseless researches, and improved processes, would they have advanced until those had become as perfect as they are important. The manufacturer of this day should proceed in like manner. His predecessors, ancient and recent, had presented for their acceptance few of the advantages placed before him; yet they scarcely availed themselves of suggestions from intelligent contemporaries. In general, practical men are known to be the slaves of prejudices; unaccustomed to read, compare, reason, judge; ignorant that by the three great stepping stones, observation, analogy and experiment, can they ascend from darkness to light; and that although the foot may accidentally be placed on the first, yet only by personal efforts can the ascent ever be completed;

acquainted with processes, dexterous in manipulations, and familiar with products, too often they regard as most presuming, in the thinking portion of the community, any suggestion for improvement in either, although in its favour may be the fullest force of reason, and clear demonstration of the advantage of the change. Restricting the Art to a certain class, and scarcely supplying correct information, or clearly explaining all the mystery during the term of apprenticeship, they do not afford opportunity for extension of principles, nor enable improvement to keep pace with the opportunities presented for the exercise of genius, even where celebrated for skill in the manufactures. The bulk of the population being partially ignorant of what constitutes excellence, indifference prevails to an extent inconsistent with public welfare; whereas, a little acquaintance with the qualities inciting to a better, whenever the public mind comprehends the different peculiarities, the most useful will be determined and approved by the general understanding and judgment.

Frequently has been repeated the adage—"He who undertakes to teach himself has a *fool* for his scholar;" and there is probability that its utterance by persons who had passed much time in colleges may have affected some weak minds, and excited a fear of ridicule. But we live in a day when numbers can be mentioned to completely negative the degrading stigma. However humble the origin of the parties, and however *great fools* they were, and least likely to supply examples of extraordinary genius and transcendent talent when their self-

teaching commenced, ere their course was completed they supplied indisputable proofs that although *self-taught* they were BEST TAUGHT; and honourable refutations of the force of the adage. What nonsense! to allow it longer to influence the public mind, when its foolishness is demonstrated by a host of persons most celebrated as original thinkers—Priestley, Davy, Dalton, Farady, A. Murray, Herschel and others in our own and other nations. What has elevated our country to its high and proud grade in the scale of nations?—The Arts and Sciences. Through which of her sons? Many of the humble and self-taught, whose industry and talents would do honour to any age and country; who have clearly and fully distinguished between hypothesis and science, and, passing the boundaries of mere scholastic literature, have carefully studied the ample and instructive page of Nature.

In each of the processes, the phenomena result when the combinative potencies of the components are affected; and he who most easily accomplishes this is the most expert analyst. Correct knowledge of the behaviour of Re-agents and Compounds in union, and dexterity in the use of apparatus, may enable him to dispense with intermediate processes, yet obtain correct results. On the composition of a substance, the reasoning from the result of its analysis, without opportunity to combine its elements, may be very clear; but only when the synthesis of like quantities and elements supplies results every way similar to those submitted to analysis, do we admit the conclusions to possess all the certainty of a mathematical demon-

stration, and the practice so far perfect. Such results gratify the analyst, and urge him "onward" to further investigations and developments. Thus have been urged Beccher and Stahl, who, on phenomena occurring, first noticed mutual solicitings of the gases and the general atmosphere. Their observations urged likewise and facilitated the discoveries of two Swedes, Bergman and Scheele, contemporaries of our Priestley and the French Lavoisier. And to the investigations of the science has arithmetical precision been secured by another Swede, Berzelius, —Fourcroy, Berthollet, Gay Lussac in France; and Dalton, Davy, and Thomson in England.

Metallurgical chemistry, important and essential to many of the Arts of Life, is yet, as regards POTTING, palpably imperfect. There may be reasons for this. The processes have been inspected by many persons fully adequate to their correct description; but they have declined promulgating the information, either because filling a station in society, regarded as superior to such trouble, or fearing lest in giving publicity to *imagined secrets* they should break some seal of confidence. Not so proceed the pioneers of science. Persuaded that there is no reason whatever why the Art should not rank as a science, and well aware that most subtile and peculiar are the processes of the Laboratory, and the energies for the constant and gradual changes by Analysis and Synthesis, separations and combinations, they resolutely in every quarter break up the ground, and throw together by far the greatest number of important facts possible to be aggregated, that the Manufacturer may understand fully the true combinative potencies and pro-

portions of the components, by whose reciprocal qualities they combine in bodies, glazes, and colours; and while for the great variety of these the same few materials are variously proportioned, the spontaneous workings of the whole are not so obvious, and the traces they leave are so delicate as afterwards to be scarcely perceptible by the most experienced eye.

With an ardour of investigation only now sanctioned, and a constant addition of products for subjects, with rapid strides Science advances to solve all important inquiries on the economical appropriation of components, diminishing the expense, yet promoting the excellence of the products and of the Art, as suggested by the wants of progressive refinement. Disregarding all impediments, the steady "March of Intellect," and the discoveries of Philosophic Research, will place the Art on an immovable basis; will give publicity to the new application of solidly established principles, to direct and expedite all attempts at alterations, and all original researches for what useful purposes different materials may be with advantage employed; will exhibit in a new light experimental facts, supplied by the united efforts of scientific men, expert analysts, occasionally named, and including many interesting inquiries which have exercised the intellect of ardent admirers of nature's processes; will no longer sanction such important products remaining the mere results of chance and guess-work, but urge to ceaseless efforts to supply data, plain and correct, for readily and certainly determining the employment of materials; will explain, if not with absolute certainty, yet satisfactorily to the mind not influenced by the specious reasonings

of theory, many questions now controverted; will supply observations and experiments on interesting and remarkable phenomena and their causes, heretofore completely mysterious; the latter often results of others more general—of principles, which, as well as the analogy of their relations, demonstrate the former and others similar; in a few words, will exhibit the manipulations and processes, conducted by the directions of science, as indubitable as are the demonstrations of Euclid, and supply the details so clear, by generalising the essential and most important combinations to the capacity of any person, that the principles may be established and the Art advanced to perfection by that unrivalled instrument of improvement, which till now it had seemed completely to elude—the mathematics. Not, however, to deny that the advancement here contemplated may have a limit, owing to the difference in men's natural ability, and their avail of opportunity to scrutinise the subjects presented (like nature's processes, sublime and profound, different though constant and uniform), leading to the search for powers and causes almost as diversified as the effects, affording the greater satisfaction with the simplicity of the principles, and the pertinence of the results. Whoever *first publishes these*, will be the manufacturer's friend; and were several persons thus employed, assuredly would valuable suggestions be made, independent of any possible petty jealousies.

The manufacturer usually affects mystery in his recipes, regarding them as cheaper, or better, or both these, than all others; though non-comparison of them with others, in components and quantities,

causes the useless expense of some which are innocuous and inefficient. The spirit of jealous exclusiveness causes great difference, as well in components as in proportions of the same component, in the current formulæ of even celebrated persons. With some trouble have been completed the comparative analysis of recipes, by their owners supposed excellent, and which well exhibit the knowledge and reasonings current in the days of *guessing* at proportions. Admitting them good and useful when first introduced, yet being altogether devoid of general principles, they are not adapted for an improved state of the Art, or to indicate any advance in the Chemistry of Masses. From the directions given, also, there might be the inference, that intentionally errors have been promulgated to cause failures and deter parties busied in research; else, that glaring errors have crept into the numbers and processes, or the parties were deficient in the knowledge and verity for which they have obtained credit. It must, however, be allowed, that, to the manufacturer, caution is indispensable, and must be observed; for, by his temerity, with himself the community would suffer, was he, because of the success of one experiment, disregarding the suggestions of prudence against the excitements of speculation, to act as well as argue from particulars to universals, and hastily compound each body or glaze proposed.

Of Operatives—the most prejudiced against any change—the Potter of the generation last past seems in the first rank habituated to regard the frequent and ready performance of a process as the only proper test of its utility and accuracy; recollection

enabling him to provide for his support with little exertion, he increased in fondness for the processes, and proportionately became prejudiced against the new, however superior in economy of labour and time. To him the name of an experimenter, on Chemical Principles, was merely a synonym for *a fool!* and the pity, contempt, or aversion of his less speculative acquaintance, was the only reward of the person who ventured to suggest the application of Theory to Practice, to ascertain the rationale of processes, to suggest the alteration of manipulations, to introduce the employment of a fresh material. Yet, has any of the prior class left proofs that he possessed the least knowledge of Principles, and, by analogy, of their reciprocal relations? As well might we give him credit for knowledge of Nature's simple modes of operation, which would suggest imitation and preclude erroneous calculations of results, as of the component elements of the several materials (of their peculiar potencies as agents and recipients) whenever, in artificial processes, they silently expand, break, evaporate, radiate, contract, disperse, or combine with others. I am disposed to regard as one principal cause of retarding the progress of this important Art, the implicit adherence to precedents and rules of days long passed, without testing those precedents by Scientific Principles, and superseding all rules but those which accord with the improved state of Society.

But, besides the Operatives, the Friends of Improvement are opposed by others, who have the peculiar taste or disposition not to suffer to be introduced into practice anything new in place of what themselves know. Until very recently—jealous of

all innovations as needless, even when harmless—the monopolists of power, and the votaries of avarice and selfishness, sternly and vigilantly obstructed advancement in knowledge and the extension of useful research, fostering whatever impeded the march of Scientific Discovery, and over-awing all attempts of Intellect to pass the limits prescribed by their opinions and requirements. They present obstacles often causing an ingenious inventor more trouble than to surmount physical difficulties inseparable from new processes; or to clearly develop and explain whatever facilitates the intended purposes.

There have been expressed doubts on the propriety of giving to the numerous *Secrets* of this Manufacture the extension and publicity that are consequent on printing them. Why any should question the utility as far exceeding any possible disadvantage, I profess myself unable to determine. The leading principle of a Manufacturer appears to be, to employ the means best adapted and most correct, to appropriate to the utmost possible use whatever materials he employs. For this purpose there seems a necessity for the processes suggested by his experience to be directed by the liberal and accurate details of science. His profits depend on the business being conducted with regularity and judgment; but how the latter must be exercised without available knowledge is not easily determined; though readily would all be effected were the Manufacturer's compounds simplified and regulated by science.

The rapid progress recently made warrants the anticipation of yet much greater in every department of valuable knowledge, because of the liberal commu-

nications of those philosophers and philanthropists who have directed their attention to promote and improve whatever to the public may be indispensable and valuable. Most of those, who, on the European continent, have thus, by the aids of science, improved the Arts of Life in very recent times, were regularly initiated into her arcana, and either passed their lives in the quiet of the cloisters, or because of well-earned celebrity were called by their country to take an active part in the drama of public life. Not such has been the fact in our own country. Our great improvers have been men of business, who did not pursue philosophy as a profession, but by mere accident found it, and then pursued it as a recreation, or, beneath its extended shelter, enjoyed relaxation from more weighty cares. Hence, while on the continent more systematic or more logical views of science were taken, England has been distinguished by more useful discoveries—as by Bergman and Lavoisier; Cavendish and Davy.

Frequently have important discoveries been completely accidental, and made by persons scarcely aware, and seldom capable of fully availing themselves, of the extent of improvement of which each was susceptible from the suggestions of science; and thus the spirit of monoply has precluded even themselves from consequent advantages of their discoveries, lest some of these should also be enjoyed by others. The vast improvements accomplished in those manufactures to which have been applied the Principles of Chemical investigations, prove the accuracy of the reasonings of Boyle: "The excellency of Manufactures, and the facility of labour, would

be much promoted, if the various expedients and contrivances which lie concealed in private hands were, by reciprocal communications, made generally known; for there are few operations which are not performed by one or another with some peculiar advantages, which though singly of little importance, would by conjunction and concurrence open new inlets to knowledge, and give new powers to diligence." To discard all mystery and quackery, and clearly to disclose every process, certainly will be to invite the attention of men of science and research, to extend as far as possible any advantage, however gained, and to discover greater utility in the numerous and various substances employed. And, by the union of varied talent, by unremitted investigation, with perseverance and acuteness in the successive experiments being connected unto comprehensive and systematic views, we shall have the beau ideal of what it is proper should be our Manufacturers. May they emulate Davy and Dalton in their bold and sedulous attempts to discover what has hitherto been concealed; and Bergman and Berzelius in their close and systematic reasonings from causes to results, and *vice versâ*. How truly applicable is this remark: "My intention is, to elucidate clearly the theory, and occasionally the *un*-philosophical practices, of the Manufacture. Those scientific details which now terrify the adult Manufacturer, will be mere trifles to his children, when they shall be taught at School—a little more Mathematics, and a little less Latin; a little more Chemistry, and a little less Greek."—DUMAS.

LABORATORY AND APPARATUS.

THE Art of Chemical Analysis consists in a most cautious and acute investigation of the structure, and the reciprocal actions and re-actions of substances. Professor Robison justly remarks: "Every change in the state of things is considered as an effect, indicating the agency, characterising the kind, and measuring the degree of its cause." And you are aware, that to closely examine these, and all the other categorical particulars of those subjects obvious to the senses, and controlled by the Laws of Nature, there has been successfully employed numerous illustrative experiments, at the expense of great labour, much scientific application, and extraordinary mental and bodily activity. Hence the utility of a Laboratory and Apparatus.

The LABORATORY, or apartment in which are pursued chemical investigations, must have a dry floor, and a temperature of 60° Fah. to prevent injury to any of the contents. It must be entirely free from the direct solar rays, and influx of dust, of persons passing through, or any disturbance by shocks of machinery. The window must easily open, and the chimney allow space for compounds while offensive gas escapes. In front of the window must be a strong table, with drawers for utensils, yet allow the person to sit close without inconvenience. In a retired part of the room fix a set of double shelves, the upper of each pair *thin* and *pierced*, to receive the phials of acids and re-agents, and preclude

accidental overturning. In another place fix a set of single shelves.

The articles of APPARATUS used in the analysis of the different materials of the manufacture, are fewer in number, and less expensive, than for preparing the different kinds of gas. These are indispensable :—

Phials for acids and re-agents, strong, broad, short, and stoppered—six each of 8, 4, and 2 oz., and twenty-four 1 oz.

Phials with wide mouth for *dry* re-agents and preparations—six each of 8 and 4 oz., and twelve of 2 and 1 oz.

Close-covered earthenware jars, 36s. to 18s., for ores, salts, etc.

Plenty of all sizes of corks, and of lengths of glass tubes.

Very small funnel, glass, ribbed ; larger of earthenware.

Watch glasses, and porcelain capsules ; several sizes.

Glass jars for mixtures, and three sizes for precipitation.

Graduated half-pint glass measure.

Two Woulfe's bottles, and several oil-flasks.

Iron and porcelain mortars, three sizes.

Hessian and small porcelain crucibles.

Platinum crucible, capsule, spoon, forceps, and foil.

Spirit-lamps, large double wick, and small single wick.

Blow-pipe and lamp. Platinum, copper, and iron wire.

Good scales ; cup set, and grains box of weights.

Flat files, four sizes and cuts ; rat-tail files, four sizes.

Four sorts of lead shot, mixed, one pound.

The quantities of the respective substances have these proportions: *Distilled water,* as much as possible (readily procured from condensing steam at any throttle-valve of a steam-engine). The purest is thus prepared—into a retort put a pint of clear rain-water ; distil over a little, and with it wash the receiver ; then distil two-thirds of the remainder, and preserve for use. *Alcohol,* 4 oz. very pure, and weaker for the lamp (unless pyro-acetic spirit be used). Pure concentrated *Sulphuric, Muriatic,* and *Nitric Acids,* 2, 1, and ½ lb. *Potash,* ¼ oz., solid, dissolve in *distilled water* (always to be understood), let it repose twenty-four hours, then decant into its own phial, and let the stopper be well rubbed with tallow. Always abstract it by the dropping tube, never *pour* it out, its action on animal and vegetable substances

being so extremely violent. *Liquid Ammonia*, 4 oz., keep well secured from air and warmth. *Carb. Potash*, 4 oz., ignite the bicarbonate crystals in the platinum crucible over the double lamp, then dissolve the calc in water, filter, and keep for use. *Carb. Soda*, dissolve in distilled water, filter, evaporate till a pellicle forms, and place aside to crystallise for the blow-pipe processes; also, dissolve in water, filter, and preserve for use. *Carbonate of Ammonia*, dissolve in water, filter, and keep cool and well secured. *Nitrate of Silver*, ¼ oz., keep in a dark place. An ounce of each of these crystals, Tartaric Acid, Citric Acid, Sulphate of Potash, Sulphate of Soda, Yellow Prussiate of Potash, Nitrate of Potash, Sulphate of Copper, Acetate of Lead, Borate of Soda, Sulphate of Magnesia, Alumine, Iron, Soda, Tartrate of Soda; half an ounce of these crystals, Oxalic and Boracic Acids, Chloride of Barium, Super-oxalate of Potash, Oxalate of Ammonia, Carbonates of Barytes and Magnesia; and a quarter of an ounce of these, Nitrate and Acetate of Barytes, Phosphate of Soda, and Chromate of Potash.

For purposes of amusement, these, as sold by respectable druggists, will answer; but for the researches which require the most scrupulous accuracy, the re-agents must be as pure as possible, and preserved in well-stoppered (not *corked*) phials, else something may enter, or escape, and spoil them. The crystals, in small portions, must be pulverised and dissolved, then filtered, and always saturated, transparent, and without deposit, except of its own crystals, as when used, a drop or two of distilled water will readily dilute. The solutions which separate spontaneously are to be made at the moment wanted.

Test-papers. Take two sheets of very thin yellow-wove post paper for each of the three kinds, and after being immersed and dried, cut into squares of two inches broad; then keep well secured from light, air, and vapours, and each square cut into six or eight strips for use.

In a pint of distilled water, boil 1 pound of *red cabbage leaves* in shreds till all the colour is abstracted; strain through muslin, evaporate to half a pint, pour into a shallow dish, immerse the paper; afterwards with alcohol odourate the liquid in a well-secured phial. Of *Litmus* and *Turmeric*, each ¼ oz. Logwood 1 oz., and a quarter of a pint of water, boil half an hour in a bowl, strain through muslin, and proceed as directed for the cabbage-leaf paper.

Most chemical preparations are deleterious, and must not be trifled with. Many of them burn whatever they touch, the fingers, or clothes, and this can only be prevented by care in using the phials: wet the stopper with the liquid, then withdraw it, and make a line on the rim of the phial, to which wet line apply the stopper, and let the liquid escape only in drops till all is obtained. Let every preparation be placed on the shelf, to prevent its injuring any person; and also be distinguished by its *label*, and its own place, to save time and diminish the trouble inseparable from the study.

The Jars for the Laboratory should be so formed that the cover can sink down and rest on a ledge in the flange. Whenever any substance is to be kept in such jar, free from air, the only addition needed is a little hog's lard on the ledge round, and more to be applied when the cover is in its place, so that it can be readily removed, and yet will always be air-tight.

The preparation of the *Re-agents*, or *Tests*, whenever possible by the student, is peculiarly useful and beneficial. Certainly they can be obtained at much less expense than that of preparing them; but I believe very few will estimate the mere purchase and application above the knowledge resulting from their preparation. By conforming to all the directions, examining every appearance and product, remarking the relative active or sluggish energies of the respective substances, there are acquired dexterity in using the apparatus, confidence in the genuineness of the re-agents for future researches; and more real information is obtained by observing all the phenomena presented by merely one experiment, than can possibly result from a partial attention to several. Whatever difficulty occurs, the greatest are those of false notions, which have to be superseded by others new and correct; and afterwards the details of processes

are more readily comprehended, and the pursuit of the science in a considerable degree facilitated.

For convenience, the several operations in Analysis and Synthesis—the separation of some and the joining together of other elements or compounds—have distinctive appellations; as *Ignition*, all its particles being red by heat; *Fusion*, melted by heat, the contrary being *infusible;* the application of heat in fusion, chemically changing a solid into a fluid substance, as Metals and Salts, which latter have the aqueous —peculiar, because of water of crystallisation present—and the igneous, solely from action of heat. *Solution*, separation in a liquid; and when not so separable, *insoluble.* Whenever the combinative potencies of the elements in the fluid exceed those of the elements in the solid towards each other, solution begins, and continues till amongst these potencies there is equilibrium; the solvent potency of the fluid is counterbalanced, the solution is saturated, and any excess of the solid remains unaffected. *Decomposition*, the separation of components by heat and galvanic action (its unphilosophical application to separation in fluids, where fresh compounds result, should be discontinued). *Evaporation*, by heat dissipating all the volatile particles of a fluid compound, and preserving all the fixed, in shallow open vessels, with regulated temperature, and either increased or diminished atmospheric pressure, as the volatile and the fixed particles have more or less difference in their tendency to be dissipated. Usually, the elements in the evaporated fluid aggregate in beautiful crystals, with regular and determined form of sides and angles, similar to the masses, and cut in the same figure as

those by nature; a regularity which proves that the fiat for their formation is—not blind chance or fortuitous motion, but the will of an Omniscient and Almighty Creator. *Distillation*, separating all volatile particles, and collecting and preserving them at a reduced temperature, as liquids. *Precipitation*, separating one element of a compound fluid by changing the condition and circumstances. When this compound has two components (as acid and oxide) besides water, on exhibiting a third (as an alkali), which solicits one of them more potently than they solicit each other, either the fresh compound, or that component which does not enter into the fresh compound, as they happen to be, relatively, more or less soluble, separates from the menstruum or mother-liquor, and *precipitates* to the bottom of the vessel. When the proportions of the components of the fresh compound are so adjusted that neither is in excess, they are in *equivalence;* and when the liquid does not alter the tint of the test-papers, it is a neutral salt. *Filtration*, obtaining what was separated in a solid state. A speedy process of mechanically separating the fluid portion of a compound from the solid, whether accidentally mixed with it, or a precipitate, by a re-agent affecting the fluid compound. It is accomplished several ways, by sponge, tow, wool, cotton, and for corrosive fluids, fine glass powder in an inverted phial; but the general practice is unsized cap paper, or common blotting paper, at times supported by linen cloth, through which the fluid permeates and escapes, while on the paper remain the solid particles, to be washed, dried, and preserved for examination or

future use. The employment of *lawns*, in the manufacture, is a kind of filtration. In some processes, repose for a length of time is preferable to filtration, as in preparing the *Purple of Cassius*. In such processes let a strip of coarse linen rag be made wet, and one end be immersed in the middle of the precipitate, while the other is carried below the support of the vessel, on the principle of the siphon and capillary re-action; all the water will be gradually conveyed away, and every atom of the powder will be preserved. *Calcination*, dissipating, by heat, some of the elements of substances, whether incombustible or not, which if present would preclude the chemical combination of the fixed residue with other substances to form fresh compounds; thus the water of crystallisation is dissipated from borax, alum, gypsum, etc., the volatile components of bones (ammonia) is evolved, and the results are—the *cinders* of common language, and the *calcs*, or *oxides* of chemical nomenclature. *Elutriation*, washing off lighter particles, leaving the heavier to subside. *Eliquation*, fusing only the more fusible of two metals. *Granulation*, subdividing for facile chemical action a melted metal, by pouring it from some height either into cold water, or a box whose sides are well chalked, and kept in motion till it congeals, when it becomes a fine powder. *Cementation*, placing a solid body in the powder of another body, and then in a close vessel subjecting the whole to a temperature just below that at which the contents would fuse. The baking of biscuit Porcelain in flint powder is a kind of cementation. *Trituration*, rubbing substances extremely fine in a mortar, porcelain, or agate; but its results are always coarse and

wasteful, compared with those from *Levigation*, the scientific name for *grinding* on a flat stone, hard, polished, and lubricated with water, oil, or turpentine. The substance is gradually and constantly reduced in the size of its particles by the motion of a stone moved by the hand, and called the muller. Its face being flat and polished, while the fluid prevents the particles fleeing around, the action and reaction facilitate the comminution. The palette-knife, or bone spatula, readily brings and keeps all the mass together. *Sublimation*, by heat separating the volatile particles of solid bodies, and again obtaining them in a solid form, in which restriction to solids it differs from evaporation. It as well purifies the substance from extraneous or deleterious ingredients as vapourises, and in that very comminute state confines principles which else would not easily have united. All fluids being volatile by heat, and therefore in most instances separable from fixed matters, hence, various solid substances are subjected to a similar process. Fluids distil, solids sublime; and sometimes both are results of one and the same process. Substances not volatile *per se*, usually can be rendered so by the presence of others; and often in close vessels the fumes rise only a little, and adhere to the part where they concrete. The result, when powder, is *flowers;* when solid, a *sublimate.*

ELEMENTS.

ALL the wonderful diversity of objects presented by nature, and recognised by the senses, are either simple ELEMENTS, remaining the same to whatever chemical processes subjected—only fifty-four being at this day known (1836)—or, compound, BODIES or substances, the reciprocal action and recipience of rarely more than *seven*, and often only *three* or *four* of the former, into which, by such processes, they are separable. Repetition of the processes, not reasoning *a-priori*, has determined this, although, from knowing all their distinguishing characters, we are precluded by the impossibility of exhibiting even any one of the former to all the others, in every possible variation of temperature and atmospheric pressure.

All language consists of words, of a small number of letters, variously arranged, to faithfully depict the sounds of the human voice, and only a few sometimes stand alone. For their analysis human intellect is by some supposed inadequate; yet the solution of this difficult problem is the signs for Letters, Syllables, and Words, in different languages, and for stenography and music. The analysis of the Principles of the mysterious science—*the Black Art*—Chemistry, has hitherto been expected on some basis or other, chiefly by those who study the science only because they may not dispense with it; while the secrets hidden in the dark abyss of nature cause others of superior minds, and intent on understanding what is known, to confess the inefficiency of current

processes to develop these Principles ; and they remain satisfied with the probable composition of Bodies.

Each of the fifty-four Elements, or undecomposed substances, has an essential peculiarity for uniting with the others. This, when presented in an abstract or separate form, in the requisite comparison of momenta with ratios of numbers assigned to all, has often been called its *Electricity ;* and when a compound of any of four (oxygen, chlorine, iodine, and fluorine, which very powerfully solicit all others) with any one of the remainder, is subjected to the action of the galvanic circuit, and decomposed, this remarkable difference is observed : at the *positive* or active pole the oxygen, etc., concentrates ; and the hydrogen, metals, etc., at the *negative* or recipient. Thus are clearly distinguished the agent and patient as the Elements of the decomposing compound concentrate at the positive and the negative poles.

With this restriction to the active or sluggish momentum, the qualities of positive and negative are attributed to the respective elements ; although only the two extremes of the Series following (copied from Mr. Griffin's Chemical Recreations) are without both kinds of momenta, active, communicative, positive with regard to all below, but, to all above, quiescent, receptive, or negative.

The following table shows, 1. The names of all the chemical Elements, arranged in the order of their relative decomposing powers. 2. The weights of the atoms of the Elements, determined by a method described hereafter. 3. Symbols, and 4. Names, for denoting the atoms of the elements.

(+)	Weight of an Atom.	Symbol of an Atom.	Name of an Atom.
Potassium	10	K	Kali
Sodium	6	N	Nati
Lithium	1·5	L	Liti
Barium	17·5	Ba	Bari
Strontium	11	Sr	Stroni
Calcium	5	Ca	Calci
Ammonium	4·5	Am	Ammi
Magnesium	3	Mg	Magi
Glucinum	4·5	Be	Beri
Yttrium	8	Y	Yttri
Aluminum	2·25	Al	Ali
Zirconium	5·5	Zr	Ziri
Thorium	15	Th	Thori
Manganese	7	Mn	Mani
Zinc	8	Zn	Zinki
Cadmium	14	Cd	Cadi
Iron	7	Fe	Feri
Nickel	7	Ni	Nicki
Cobalt	7	Co	Cobi
Cerium	11·5	Ce	Ceri
Lead	26	Pb	Plumi
Tin	14·5	Sn	Stani
Bismuth	18	Bi	Bisi
Uranium	35	U	Uri
Copper	8	Cu	Cupri
Silver	27·5	Ag	Argi
Mercury	25	Mr	Meri
Palladium	6·5	Pd	Palli
Platinum	12·25	Pt	Plati
Rhodium	6·5	R	Rhodi
Iridium	12·25	Ir	Iri
Gold	16·5	Au	Auri
Osmium	12·5	Os	Osmi
Hydrogen	·25	H	Hydri
Silicium	2	Si	Silli
Titanium	3	Ti	Titi
Tantalum	15	Ta	Tani
Tellurium	8	Te	Teli
Antimony	11	Sb	Stibi
Carbon	3	C	Cari
Boron	1	B	Bori
Tungsten	8	W	Woli
Molybdenum	12	Mo	Moli
Vanadium	17	V	Vani
Chromium	7	Cr	Cromi
Arsenic	9·5	As	Arsi
Selenium	10	Se	Seli
Phosphorus	4	P	Phosi
Fluorine	4·5	F	Fluri
Iodine	32	I	Iodi
Bromine	20	Bm	Bromi
Chlorine	9	Cl	Chlori
Azote	3·5	Z	Zoti
Sulphur	4	S	Suli
Oxygen	4	O	Oxi
(—)			
Water	4·5	Aq	Aqui

Numerical exponents, or names denoting any number of atoms up to 12.

1 = mona
2 = dia
3 = tria
4 = tetra
5 = penta
6 = hexa
7 = hepta
8 = octa
9 = enna
10 = deca
11 = endeca
12 = dodeca

p—signifies the positive element in excess to the extent of 1 atom, if not otherwise mentioned

n—signifies the negative element in excess to the extent of 1 atom, if not otherwise mentioned.

The Numbers indicate the precise arithmetical proportions, or definite relations of the single atoms, by weight, determined by experiment, examination, and analysis, of the mutual, fixed, and resulting quantities, one to another, in which they ever and only form regular compounds.

It must be understood, that, with reference to the *real nature* of the Elements, all is conjecture. We assume, however, that each kind of atoms, in accordance with Nature's general laws, peculiar in shape or form, with orbital space of determined size, invisible to us, yet included in the general atmosphere.* The *atoms* of vulgar regard, whose aggregation in a determined space constitutes *density* and *weight*, are

* The French mathematician, Poisson, has calculated the manner in which *Electricity*, or, in fact, these orbital spaces, may exist, and be affected. From his remarks I have selected the following as most pertinent, adapting my own language :—

Around each atom is an orbital space, varying in shape and size with those of the atoms ; its thickness at every part depending also upon that shape, yet preserving the equilibrium of the atom. The problem is always reduced to determining the shape of the atom. The quantity is always proportioned to the surface. The thickness in each point of the surface, to preclude irregular action of the atom, must be greatest at the summit of the longest of the three axes, and smallest at that summit of the shortest ; and these also be to each other as the length of the axes. Was the stratum of this orbital space very thin, its distribution round a spheroid will vary little from a sphere. But the varying thickness can be estimated by current knowledge only in regard of the spheroid and ellipsoid. Suppose the atom a sphere, the orbital space is equally thick over every part of the surface. Suppose it an ellipsoid, the orbital space would be relatively thick at the extremities of the longer axis, and thin at those of the shorter, and the whole will assume the form of an ellipsoidal shell, the interior surface ever coinciding with the shape of the atom.

those parts of substances which by continued trituration may be reduced smaller and finer, yet retain their characters and relative properties. Chemistry presents others to her votaries, the principles which

That the reciprocal actions and re-actions of atoms are as the inverse of the square of the distances is demonstrated by the coincidence of calculation with the phenomena. When the orbital spaces of component atoms in a body are undisturbed by supplied or abstracted motions of heat, such body is in its natural state. On adding a determined quantity of one kind of atoms, these with their orbital spaces distribute motions to those of the body, and the whole are alike affected. When two excited atoms are in contact, the point of contact is neutral, or without physical energy; and the greatest quantity of orbital space is accumulated at the point most remote therefrom. The quantity for each increases from that to the maximum point, according to the relative diameters of the two atoms. The thickness being nothing at the point of contact, two spherical atoms, with like momenta in contact, are at this point without action or re-action. Around it, and even to some distance, the momentum is very weak upon each atom, and the expansion small, and where appreciable, it at first is more powerful in the larger atom, and afterwards increases at the greatest rate on the smaller, so as to be upon the point diametrically opposite that of contact, always greater on the smaller atom than in the corresponding point of the larger. When removed beyond all reciprocal solicitation, each separated atom is uniformly surrounded and accompanied by the whole of its orbital space.

The formula of the action and re-action of spheriods supply data to calculate those of the orbital space for a point in any part thereof. In proportion to its thickness is its re-action in each point of the surface of a spheroid, little differing from a sphere; and the like regards the surface of an ellipsoid of revolution, whatever be the ratio of its relative axis. In these two shapes of atoms the orbital space would most re-act where was the greatest momentum. La Place has, by synthesis, satisfied mathematicians that always is the re-action proportional to the thickness. We are not certain that it varies at the surface of atoms in motion, or is proportional to the square of the thickness. Whenever its

constitute all other substances, and remain unaffected by current processes of analysis.* Although the word *atom* precludes the idea of half-atoms as absurd, and indicates the smallest imaginable portion of an

expansion has momentum greater than that of the other atoms, entry and admission of the orbital spaces, especially from pointed or sharp-edged extremities, combination results.

The analysis applies equally to action and re-action, affecting the same atom at the same instant. Suppose one atom excited only as much as by the atom presented, then the combinative recipience in re-action to that of the great atom, accumulates nigh the least distant point, while nigh its opposite point accumulates similar combinative recipience. In these points the reciprocal potencies are almost equal; and the line of separation differs little from the grand circle perpendicular to the line which joins the two centres, and equally divides the little atom.

* Döbereiner thus assumes the different sizes of atoms of gases: In a large glass that had a very minute fissure, hydrogen was left standing over water, and in twenty-four hours the water had risen almost three inches, without any sensible alteration of the barometer and thermometer, and this always occurred whenever the vessel had fissures, but never when the vessel was covered by a bell-glass, or when filled with atmospheric air, oxygen, or nitrogen. Regarding all gases as consisting of solid atoms of varied size, enveloped by orbital spaces, as atmospheres of heat and likewise very different, hydrogen, with the smallest atom, has the largest orbital space, or atmosphere of heat, and therefore may escape through fissures which retain the other gases; as other fissures may allow nitrogen to escape, and yet retain oxygen, others similarly allow oxygen to escape, but retain carbonic acid gas. He mentions also this remarkable probability, that a tube will admit air, yet not admit alcohol: A thermometer tube, finely drawn out by the lamp, to fill with alcohol, had the point immersed, and the bulb heated till no air-bubbles escaped, and yet when cooled, no alcohol entered. Being again heated, bubbles passed out through the alcohol; still, when cooled, no alcohol entered. The tube through a lens appeared open, and when taken out of the alcohol, the air hissed on entering it.

element, the fancy associates therewith a portion of universal space in which it exists and is movable, and whose diminution or enlargement, contraction or expansion, capacitates it for combination or separation. This is the true cause of what is mentioned in many chemical works as a "natural tendency [in the elements] to approach each other, whatever be the distance at which they are placed;" although these mechanical effects are, confessedly, efficient only "when [the elements are] placed in apparent contact."

The *Electricity* of the elements is easily explained. Every instance of the mutual action and re-action of

The oxy-hydrogen microscope of Brown demonstrates the existence of circular or orbital motions in every substance investigated; and M. Muncke exhibits them by this easy method: On a glass-plate triturate the size of a pin's head of gamboge in a large drop of water; and in this dip a pin's head, and in another drop of water mix well the fluid taken; of this take half the size of a millet-seed, suppose 0·5 of a line, place it under the magnifier of 500 power, and there will appear brownish-yellow points, round and elongated, similar to fine grains of gunpowder, distant from each other 0·25 to 1 line, but all in constant slower or quicker motions, so that they move through the apparent space of 1 line, in from 0·6 to 2″ or 3″. When oil of almonds is used, these motions do not appear; but with alcohol they are almost too quick for recognition.

Suppose that the magnified side is more than 18 inches of water, with particles moving in it, and the motions being proportionately magnified, and all wonder immediately ceases. These motions are governed by the principle of action and reaction, which requires, when atoms are solicited, equal space ever to contain equal momentum. To preserve this, they have equable effect, indifferent to their being orbital, as results of reaction on a rectilinear force, and, to the atoms uniting in one orbit, or moving in concentric circles, or continuous rings, or parallel planes, or at right angles. And, however confused the primary motions, orbital motion results from rectilinear motion and resistance.

oxygen and hydrogen, and their combination, produces flame and light. Heat presents the excited spheres of light, changes, and decompositions—the union of oxygen with the excited hyrodgen of a combustible, producing fire and flame; and Electricity exhibits the excited atoms with expanded orbital spaces, destructions and dispersions—the oxygen and hydrogen separated, yet in energy again to be reunited. The respective excitements thus differ: the excited hydrogen in flame needs carbon when oxygen localises the electrical result; but in the other the pure oxygen and hydrogen are separated from the circumbounding space, and artificial obstruction is interposed to delay the constantly solicited combination. How remarkable is the fact concerning hydrogen and oxygen, which in our day are known each to solicit and be solicited by the other as antagonist principles, that the idea of there being two such principles, whence originate all other substances, was entertained in a period long anterior to the doctrine of their being four Elements. But the simplicity and perfection of nature astonish us. Like every other result of infinite wisdom, the ground-work is plain and simple, the super-structure noble and magnificent, the causes few and efficient, the effects innumerable and complete, the course most easy and direct, the means the fewest possible to accomplish the design, surprisingly varied, constantly uniform; the processes manifest or less obvious might induce a search for multifarious causes, only for the satisfactory simplicity of the first principles.

Who can with indifference behold the subtlety, the minuteness, and the perfection of the mysterious

union of the elements into compounds with Protean figures because of varied proportions. Who, arrived at manhood, imagined in his boyish days, or heard mention, that water, light, and heat are different quantities of only the same two elements; that the substances called *Earths* are metallic oxides; that our table-salt and nitre are strictly compounds of soda and muriatic acid, and of potash and aqua fortis, each so entirely unlike either of the components. That on the compounds presented by nature combinative potency confers durability, indestructible by ordinary circumstances; while all devoid of these characteristics are evanescent, accidental, or only the productions of the laboratory. These discoveries, and all others in this interesting science, arise from the principle of *separation*, or analysis, by motions of the atoms in heat, or by a third, mechanically introduced, uniting with one of those previously present at the precise instant of separation, the required element being left disconnected, to be investigated and employed.

"All the Processes and Manipulations of the Science (Sir R. Phillips says) resolve into this law: The leverage of sharp tools is not sufficiently fine to change, condense, expand, and convert substances; therefore, their atoms are by motion heated, or by heat set in motion; and their relations being disturbed, they separate, or decompose. The motions may be affected by figures and densities; but the atoms being once affected, heat is evolved;" "for," says Davy, "the laws of the communication of heat are precisely those of the communication of motion.

And only does the motion of heat pass through bodies after it has put all their atoms into uniform motion."

The task is not very easy to develop and determine the problem—by the processes of Chemistry to quickly produce results which, by those of nature, need an unknown period of time. Many substances, with external differences apparently complete, present common characters, by which we trace transition from one to the other. The investigation of the properties of substances or components is productive of advantage; every step in the inquiry extends the limits of the prospect, and is rewarded with enlarged ideas. We constantly regard a regular succession of general causes as producing uniform results; and rather than question these, even occasional interruptions of the order and continuity of the series, we refer to particular circumstances. We know only few of Nature's agents, and few principles to explain them; yet their difficulty of comprehension should render us more scrupulously attentive to their investigation; and sound philosophy demands that we admit phenomena we cannot explain. Increasing additional proof of the admirable and truly grand simplicity of Nature is the most obvious fact that she conducts us most directly to discoveries, when she presents facts wholly opposed to our opinions.

COMBINATIVE POTENCIES OF ELEMENTS.

EACH of the elements respectively has combinative potency, always proportional to the momentum consequent on change of state, as either agent or recipient. In these states two elements always produce a compound, the communicative and receptive potencies being ever equal and opposed, one never exceeding the other, because no portion of the property must be unappropriated.

No kind of element, or of substance, *per se*, has, or can have, active potency. Potency is matter in motion; and, quantity being alike, potency and motion are convertible terms; for all potency is transfer, or concentration, in the direction of prior potency; and when we say that an element has potency, we mean that it has motion, and *vice versâ*; the cessation of motion, or indifference to potency, being quiescence or neutralisation. Indeed each of the elements, as all matter, is essentially inert, without potency, except mechanical, derived and connected, with equal and similar origin, process, and results; and whose complicate, involved, and only efficient momenta produce all phenomena.

Chemical research hitherto has failed fully to develop the true cause, why, in all matter, however comminute the particles, each of the component elements has a peculiarity, probably as varied as themselves, to receive and sustain a certain momentum of combinative potency towards each other, causing the chemical formation of compounds or

bodies. And yet, apparently to envelop in mystery, ignorance of the general facts, and whether the effects are, or not, results of difference in the conformation, have been employed mere poetical figures of speech, the unphilosophical and occult terms, *Attraction*, *Affinity*, and *Repulsion*.

To calculate phenomena and results correctly we need certain knowledge of the sum of these varied reciprocal momenta. Morveau, Kirwan, and Berthollet failed to solve the problem. Yet the patient exercise of common sense, the aid of mathematics, and the laws of mechanics, now demonstrate that they all are mechanical effects in an arithmetical or geometrical series. Motion implies as well as effects some alteration of the combinative potencies; but their momentum, communicative or receptive, and much varied in degree, as active or sluggish, always equals that of a single atom of each component element, multiplied by the sum.

The science assumes that bodies are compounds of at fewest two kinds of ultimate indivisible atoms, each kind having a different weight, as already exhibited, page 28; that only do single atoms, and simple multiples of atoms, combine ultimately, while bodies chemically combine proximately; that only by the principle of ultimate composition can be properly arranged and determined the real characters of chemical products; and only by that approximate composition are explicable many phenomena of analysis and synthesis.

The fact is truly remarkable, that every chemical experiment and determination of the most expert and accurate analysts demonstrates this important pheno-

menon, that chemical combination is ever the result only of perfect suitability of components, with combinative potencies that have momenta ever immutable and invariable to form like compounds through all nature, whenever affected by the addition or diminution, the more or less, of motion, than previously existed. Every perfect artificial, as well as every natural body, is composed of various elements having varied momenta towards each other—necessarily the results of their communicative and receptive potencies being appropriated, with arithmetical precision, and mechanical order; or, of compounds, with these reciprocal characters, affected usually by altered temperature, and possessing chemical properties different from those of either component alone. Every compound which has one element in common, and even its smallest particle, when combining with any other substances, so combines as to contain of this common element certain restricted or *Definite Proportions*, either equal weights, or one, two, three, four, or more multiples of the primary weight, and only in such proportions.

This principle, first developed by a Dublin chemist, Mr. Higgins, by Bergman, Kirwan, and Wenssell, and perfected by Richter, Berthollet, Wollaston, and Dalton, and so followed up by Fourcroy, Chaptal, Davy, and Thomson, has made us intimately acquainted with the ratios of the weights of the elemetary components of many hundred compounds.

Why these combinations *must be* thus in multiples there is only conjecture. Was each elementary atom a solid sphere with an orbital space, compound

particles might have other shapes, without contact of the solid atoms; while the orbital spaces might be affected by the supply or lack of the motions of heat. Also, was a limited space partially filled with atoms, or particles, whose interstices would admit others of various size, figure, and momenta, it is clear that these atoms must be in only relative numbers with determined though different forces, the compound being governed by their respective sizes.

The chief and grand secret of the Analyst being correct knowledge of Combinative Potencies in his processes to combine or separate elementary components, I consider that it cannot be too clearly explained and elucidated.

The poles of the galvanic circuit have fully exhibited the ratios of the momenta of combinative potency in each element. The difference of the atomic motions, of particles at sensible distances, and of atoms at insensible distances, as communicative and receptive, are the causes of combination being rapid or sluggish.

The following have been considered the laws of potency, and additional remarks will show how they apply: 1. *Combinative potency* is efficient only and ever when dissimilar substances or elements are placed in contact. 2. This is most rapid when the substances are extremely comminute. 3. This is promoted when a fluid is present. 4. This may affect two or several elements or substances. 5. This is always accompanied by altered temperature. 6. This produces compounds different from either component. 7. This has momenta exceeding those

of the components, and causing precipitates. 8. This differs in different substances. 9. This is limited in certain substances.*

Water solicits and separates the elements of more substances than any other fluid at temperatures between 32° and 212° Fahrenheit. *Distilled* or pure water most exerts this property, holding the components separate as little altered as possible. Impure

* These are exemplified in the following substances: 1. Muriatic acid and soda, muriatic acid and mercury, nitric acid and copper, nitric acid 3, water 3, mercury 1; lime-water and oxalate of ammonia, solution of muriate of barytes and sulphuric acid, solution of nitrate of lead and sulphuric acid, solutions of muriate of antimony and phosphate of lime in muriatic acid, added to plenty of ammonia and water, acetate of potash 2, sulphuric acid 1. 2. Metals in acids, gums in alcohol, alum in water. 3. Citric acid and carbonate of potash dry and in water, tartaric acid and carbonate of soda similarly, nitrate of potash and sulphuret of antimony, mercury and sulphur. 4. Fusible metals, soda, potash and tartaric acid, sulphuric acid, alumine and soda. 5. Alcohol and water, muriate of ammonia and water, sulphuric acid and water, dilute sulphuric acid on iron, equal weights of nitrate of potash and muriate of ammonia in water. 6. Table salt, of chlorine and soda, glass of sand and potash, verdigris of acetic acid and copper, vermilion of mercury and sulphur. 7. Solutions of sulphate of iron by that of soda, of nitrate of mercury, or nitric of silver by muriatic acid, of acetate of lead, or muriate of barytes by sulphuric acid, of sulphate of magnesia by that of potash. 8. To solution of nitrate of mercury add fine filings of copper which dissolve as the mercury precipitates, add fine filings of iron which dissolve as the copper precipitates, add zinc filings which dissolve as the iron precipitates, add ammonia and the zinc precipitates, add lime and the ammonia evolves, add oxalic acid and the oxalate of lime precipitates, leaving the liquid very dilute nitric acid. 9. Undetermined water and alcohol, or water and sulphuric acid; but only a determined quantity of water and salt, alcohol and resin, nitric acid and lime, and muriatic acid and soda.

water much affects the substances by admixture of foreign ingredients. Hence the practical utility and importance of humid chemical analysis of substances, which, by the aid of pure water, presents their proximate components, and often their ultimate elements. It is best procured as the intermediate product from rain-water, rejecting the first and the last products. It is beautifully transparent, colourless, without odour or savour, feels soft, and most readily wets the fingers, and continues clear and limpid when we add the most exquisitely sensible re-agent, as nitrate of silver, solution of oxalate of lime, or of muriate of barytes, and in a silver capsule evaporates without residuum. Free from any accidental soluble component, it has least weight, and remains unaltered however long time kept in well-stopped vessels. Under barometrical pressure of 29·8 inches, and temperature of 60° Fahrenheit, its specific weight being always the same, it is the standard of specific gravity; and freezing at 32°, and boiling at 212°, these degrees are the standard for thermometrical division. Next in purity are rain, snow, and ice-waters; but others may have volatile substances present, as well as soluble solids.

The trouble of procuring an adequate supply may have prevented its employment in washing the colourific oxides, and grinding of the biscuit and enamel colours used in the manufacture. Yet that their brilliance would be promoted thereby, I feel well convinced; and its adoption is warranted by its advantage and indispensable presence in every one of the nicer humid chemical processes.

Substances can be either mixed, or combined, into

bodies. Their gross union is mixture ; thus sand and potash may be mixed, and when solicited by water they will separate without their nature being changed, although that of the solvent is altered ; but supply motion to the atoms by heat, and however either sluggish or active in one state, and the contrary in the other, their most minute particles unite, their elements combine into a body with characters entirely distinct and different from those of either substance and their elementary components, and a prolonged high temperature causes the chemical combination of the sand and potash into glass, which water does not separate. The atoms, not merely the gross masses, being combined more or less readily, and the recognised characters of the separate components being changed, the compound is inseparable by any mechanical means ; and only can this be effected by the solicitings of heat, acids, or other solvents, when all the components have precisely similar circumstances.

Because in only few instances solid bodies combine, always accompanied by fluidity, chemists usually consider fluidity in one component brought into contact as indispensable to chemical phenomena : *corpora non agunt nisi sint fluida.* Certainly the liquid state, or that of gas, is most favourable, because of the opportunity afforded for the full exercise of the atomic motions, co-extensive in the same plane whether vertical, concentric, etc., for only in liquids, or gases, have the atoms specific motions, in various degrees opposing the force of mechanical cohesion. Motion is ever opposed to cohesion, and its diminution or absence promotes fixation.

Gay Lussac first demonstrated that the gases

combine by weight, or volume, the components being in either equal number of volumes, or the excess always in some regular multiple, 1, 2, 3, 4, of the primary volume ; thus 1 of ammonia and 1 of muriatic acid form 1 neutral muriate of ammonia ; 1 ammonia and 1 carbonic acid form 1 neutral carbonate of ammonia, the weights being as those of the substances employed to form them ; and, consequently, whether combining by weights or volumes, the proportions are definite, and the numbers for the gases are those for their base.

When one of the two substances brought into contact, at the temperature of the experiment, is a fluid, the combinative potencies of its elements solicit and separate those of the third substance exhibited. Their momenta differ with the substances, as well as with their elements, and their existence and operation are demonstrated by the solid substances which result from the contact of elements.

Such fluid is termed a *solvent*, or *menstruum*, the mixed liquor a *solution*, and the solid body *dissolved ;* and the solution is *saturated* when a portion of the solid remains undissolved. Yet this saturated solution is passive to only that substance, and frequently has combinative potency with other substances, much exceeding that of the primary fluid.

When an element is exhibited to a compound, its combinative potency, its varied rapid or sluggish atomic motions, will solicit, or be solicited by, that of one component, or those of both, and there result separation of the former and formation of a fresh compound. When to solution of nitrate of lime we add solution of pure potash, this solicits and

combines with the nitric acid, leaving the separated lime to precipitate.

This has been called *simple elective attraction*, and also *simple affinity*, concerning which we may say a few words: All known elements are termed *simple*, only with reference to current ability to decompose them. What is then the simplicity of this simple elective attraction? Daily discoveries of contemporaries enable them to separate substances, supposed elements only a few years ago. But, independent of this difficulty, there is present in all humid processes water, whose elements, oxygen and hydrogen, much modify the character of bodies immersed or suspended therein. The variations of temperature, whether by change of form in the substances, mere modification of parts, or communication of the motions of heat, negative the strict application of the designation to any experiment whatever.

When two binary compounds, or which have each only two elements present, are placed in contact, the separation of each ensues, and they mutually exchange elements, causing the formation of two fresh compounds, each with a character different from those of the prior compounds, and of their primary elements. Some saline solutions exchange principles without evident change of properties; yet change of properties always implies chemical combination.

Place in contact solutions of nitrate of silver, that is, nitric acid and oxide of silver, also common salt, that is, muriatic acid and soda; the nitric acid will solicit and combine with the soda, and the muriatic acid similarly with the silver, and two fresh compounds result. Again, saturate nitric acid

with oxide of mercury, dilute with pure water, into a dilute solution of nitrate of mercury. Saturate sulphuric acid with potash, into a solution of sulphate of potash. Add mercury alone to the latter solution, it will combine therewith; the acid will solicit the metal, yet not separate from the alkali by which it is solicited. In like manner add nitric acid alone, and, although their reciprocal combinative potencies are great, the alkali continues combined with the acid it had previously appropriated. But, mix the two solutions, and immediately there ensue separation and a change of elements; the sulphuric acid, separated from the alkali, combines with the mercury; the nitric acid, separated from the mercury, combines with the potash, and by evaporating and crystallising are obtained separately the two fresh compounds, sulphate of mercury, and nitrate of potash. In the process the most remarkable phenomenon is, that the united momenta of the combinative potencies of the sulphuric acid and the mercury, and of the nitric acid and the potash, exceed the sum of those of the sulphuric acid and the alkali, and of the nitric acid and mercury; and only because the sum of the two last is less, are separated the primary combinations. Nitrate of Mercury 40·75, + Sulphate of Potash 22 = 62·75; and Sulphate of Mercury 44 + Nitrate of Potash 25·5 = 69·5.

Fluids whose components have combinative potencies with equal momenta instantly combine; while others in which they vary have different times for this purpose, longer or shorter, to separate each other's components, and constitute fresh compounds. The atomic motions are accelerated, or heat is absorbed,

when fluids result from dissolving solids; and diminished, or heat is abstracted, when the substances solidify. In this reaction often do the particles form crystals, whose varied shapes demonstrate the previous peculiar motive power, and different passiveness to the action, or the elastic pressure of the atmosphere.

When two solid bodies are placed in contact, with combinative potencies as those last mentioned, a fresh compound results. When sulphur and subcarbonate of potash are brought into contact by the motions of heat, and form liver of sulphur, the two substances may be imagined so extremely subdivided as that only one atom of each combine into a particle of the fresh compound, and chemical sepation would give only the sulphur and the potash.

When two substances, with equal but opposite potencies, communicative and receptive, are placed in contact, indifference, quiescence, or neutralisation might be imagined from the absence of phenomena, except that a fresh compound results, with characters wholly different from those of either primary components, and solely by addition of one of those, or a different potency. From this phenomenon is the inference—that no results appear, when, to a compound, is exhibited a third substance, which solicits, or is solicited by different momenta of those elements, yet superior to that which combines the elements of each particle in the primary components; but when the potency in either is greater towards this combination, the former two combine, and the other is separated. The change of characters by combination, and of temperature, shape, and colour, ensue, without the potencies governing the specific gravity of the

fresh compound, which usually exceeds what would be inferred from those of the primary elements.

The combinative potencies of elements to form a compound continue while any of them in contact remain unappropriated, unless when one is in excess, as in *super* and *sub*-salts. But they must be distinguished from atmospheric pressure on the mass, the power which retains in contact the respective particles, or *cohesion.*

Those substances which in all proportions chemically combine with others, or to the point of saturation, have weak potencies, all multiples of the first or least combinative momentum, and often the characters of the separate components remain distinguishable; yet certain relative proportions of water and acid form powerful, permanent, and peculiar compounds. Those Bodies which combine in only one proportion have more momentum, and strong potencies; the fresh compound is close and determined, and the new characters supersede those of the respective primary components. Likewise, in those bodies which combine in several proportions are these determined, and only these, without any intermediate of the compounds; and the potencies are multiples of the least momentum. Suppose the least proportion of momentum of B's combinative potency with A indicated by 16, and that of A with B by 24, then A can combine with 32, 48, or 64 of B, but with no intermediate momentum.

One compound may be a component of another, by a second momentum, and combine in this multiple, or equal momentum, of one of its elementary components, because thereby more potent; and this

fresh compound similarly with a third, and possibly this with a fourth. For, when a compound of two elements, communicative and receptive, is brought into contact with other elements, their potencies are energetic, and all become participant.

Sometimes a compound of two elements, A B, remains indifferent to the soliciting of the momentum of C's potency, or of D's separately; but, on exhibiting their combined momenta, these may exceed those of the former, and cause separation of elements, until the fresh compounds bear that certain proportion to the elementary components which they bear to each other. And when a series of compounds have similar character, and also the same elementary component, the distinctive nature is usually, perhaps justly, assigned to the potency of that element.

Suppose two or three different substances, A, B, C, were solicited by another, D, under the same or like circumstances; then A may combine with B, indifferent or sluggish to C and D; or either C or D may solicit A to separate from B, or *vice versâ*, and a fresh compound ensue. The united momenta of A and B may exceed those of C, yet circumstances may cause C efficiently to solicit A + B. And, on exhibiting together the momenta of A + B + C, A, B, in equivalence, often ensue two distinct compounds of B + A, and B + C, agreeably to the proportions present of A and C. When exhibiting C to the compound A B, it may so solicit a portion of the compound, and the remainder may solicit an additional portion of B. Or, C exhibited to A B, may solicit some portion of A, and the liberated portion of B may solicit the unappropriated portion of C. The more the

recompositions the more of B is liberated, and the greater opposing potency against C soliciting A. When the momenta and the potencies are in equilibrium, all phenomena cease of separation and combination.

The precision of arithmetic must never be warped for theory, and most especially in applying science to the combination of the Earths in this manufacture; while the numbers themselves are brought very low the better to facilitate the perfection of Analysis and Synthesis. I have been most agreeably surprised that all the Materials for bodies, glazes, and colours have combinative potency whose momentum is some multiple of the number 4, and the strict accordance is not a fancy or conjecture, but indisputable matter of fact.

Silica	consists of	2	Silicium	4+1	Oxygen	4= 8
Alumine	Ditto	2	Aluminum	8+1	Ditto	4=12
Magnesia	Ditto	2	Magnesium	6+1	Ditto	4=10
Lime	Ditto	2	Calcium	10+1	Ditto	4=14
Barytes	Ditto	2	Barium	35+1	Ditto	4=39
Boracic Acid	Do.	2	Boron	2+1	Ditto	4= 6
Manganese	Ditto	2	Manganesium	14+1	Ditto	4=18
Chrome	Ditto	2	Chromium	14+1	Ditto	4=18
Soda	Ditto	2	Sodium	12+1	Ditto	4=16
Potash	Ditto	2	Potassium	20+1	Ditto	4=24
Lithia	Ditto	2	Lithium	2+1	Ditto	4= 6

The principle has never been yet promulgated, and I am ignorant that it has been attempted, although there appears a need for it to be fully investigated and adopted to facilitate correct conclusions, and when mistakes occur to remedy them as soon as detected. When the above numbers are doubled,

as adopted in Henry, Brande, etc., they are all multiples of the primary number, determined by repeated and varied experiments. We find Lithia $3 \times 4 = 12$, Silica $4 \times 4 = 16$, Magnesia $5 \times 4 = 20$, Alumine $6 \times 4 = 24$, Lime $7 \times 4 = 28$, Soda $8 \times 4 = 32$, Manganese $9 \times 4 = 36$, Antimony $11 \times 4 = 44$, Potash $12 \times 4 = 48$, Barytes $19 \times 4 = 76$, Lead $26 \times 4 = 104$, Boracic acid $3 \times 4 = 12$, Sulphate of Lime, and Phosphate of Soda $15 \times 4 = 60$, Borate of Barytes $23 \times 4 = 92$.

Suppose the indices for Silica, Alumine, Magnesia, Lime, Barytes, and Manganese respectively be a, b, c, d, e, f, and for Lithia, Soda, Potash, Boracic Acid, a', b', c', d', their combinative potencies are in strict arithmetical ratios; the number opposite each respectively indicates precisely the momentum of each when soliciting a' of the second, and b', c', d' the like when soliciting a. Thus the given sum of grains of the first will completely saturate, neutralise, or render inert the like number of any of the second.

Silica	$4 \times 4 = 16$	a	Lithia	$3 \times 4 = 12$	a'
Alumine	$6 \times 4 = 24$	b	Soda	$8 \times 4 = 32$	b'
Magnesia	$5 \times 4 = 20$	c	Potash	$12 \times 4 = 48$	c'
Lime	$7 \times 4 = 28$	d	Bor. Acid	$12 \times 4 = 48$	d'
Barytes	$19 \times 4 = 76$	e			
Manganese	$8 \times 4 = 32$	f			

And because each given quantity of the first series combines with c' 48 of the second, its combinative potency is precisely, but only, the same in that quantity as in a'; and as each of the second series combines with $a = 16$ of the first series, that given quantity

of each element has precise equivalence of combinative force with the assigned sum of that of each of the others in both series; consequently, any two are in the precise proportions to combine into a regular compound. Whenever in the compound these proportions of the elements, or momenta, are thus strictly supplied, the several combinative potencies are neutralised. And the numbers for the weight of each component ascertained in any analysis need only to be regarded to understand how nearly will be the results of its combinative potencies to the momenta employed in nature. Also by these numbers can we estimate momenta which would not be exhibited to our observation, like to data in mathematical disquisitions. By analysis we are presented with the *maxima* and *minima*, the limits of error and degrees beyond which our elucidatory experiments and determinations cannot be inaccurate; and perfect accuracy is the object towards which all our efforts should constantly approximate.

Every substance is formed of one communicative component and one receptive, each being either an element or a compound. We may be certain that the compound A B is formed of the communicative element A and the receptive element B; the compound A A B of the comparatively communicative compound A B and the receptive element B. But these do not determine nor explain whether in the compound A B C the three elements simultaneously combine, or A B solicit C, or A C solicit B, or A solicits B C; nor whether in the compound A B C C the elements combine as A + B C C, or A B + C C, or A B C + C, or A C + B C, or A A C + B B C C C.

We know the elements, and the sum of momenta, A B C, the *ultimate* composition; and how they are solicited into *proximate* composition, science has to develop for her votaries to understand. This very important problem must be carefully solved—not conjectured.

Many deductions of the science have been hastily and only partially drawn, without regard to all the circumstances which modify combinative potencies. And because of this, although the subject is one of very great importance, up to the time of this going to press there is not published a correct and constant method by which to determine, in any substance, whether an element is present in only one, or in a certain multiple, of its combinative potencies. The remark may not be so palatable as even I might desire; but truth and duty to my subscribers compel me to declare, that, of the several methods promulgated for this purpose, that by DUMAS is a *mere guess;* GMELIN, a *perplexity*, because of *indecision;* TURNER, a *supposition* from an *assumption;* DALTON, an *assumption*, by experiment proved *erroneous;* THOMSON, a convenient application of the names, *neutral salt, atom of acid, and atom of base;* and BERZELIUS, an *assumption without proof*—atoms of gas, we can *measure;* atoms of solids, we can *guess.*

Temperature is a most important circumstance in the action of the combinative potencies. Its varied momenta on different compounds are remarkably obvious in sometimes promoting, and at others preventing, combination; they always affect, and often reverse, the results of combinative potency.

A notion is prevalent, founded on an hypothesis, but hitherto unconfirmed by direct experiment, that the effects to which I refer are consequences of the materiality of heat. Hereafter it will be demonstrated (*See* TEMPERATURE) that it is the supply of motion to the component atoms of the substance.

Combinative potencies are always alike at the same temperatures, but alter with change of temperature; for when this is very high the orbital spaces of the atoms are so expanded as to destroy the juxtaposition of the solid atoms which existed while the motions of heat were absent, and no longer is each atom sluggish. I am not prepared to deny or affirm that during these motions from change of temperature the atoms of the components receive a kind of magnetic polarity to reciprocally solicit each other: and that they so concentrate, or intermingle, or disperse, as to produce equilibrium, neutralisation, or chemical combination with the supply, or the withdrawal of the motions of heat. Consequently, combination is more facile among similar than dissimilar substances.

To a solution of nitrate of potash add alcohol; at the common temperature, 59° Fahrenheit, it mixes with the water, and the salt is precipitated; but raise the temperature to 600°, and the alcohol will be volatilised, and the salt will be re-dissolved. Add sulphuric acid to a compound of phosphoric acid and lime, at the common temperature; the compound will be separated, and the phosphoric acid liberated, but the high temperature of this liquid, the combinative potency of the sulphuric acid, will solicit that of the lime, and separation again ensues: the latter

is again solicited to combination with the phosphoric acid. Raise mercury to the temperature of 550° Fahrenheit, from the atmosphere it will solicit and combine with 14 or 15 per cent. of oxygen, and become the red oxide; but raise the temperature to 700°, and the oxygen again will resume its gaseous state, and leave metallic mercury.

The acknowledged imperfections of the science also cause some difficulties. The character of any compound cannot depend more on the nature than on the proportions of its elementary components, for a remarkably small variation in these latter causes a consequent difference in the estimated and valuable properties. Hence the necessity of discrimination on effects from circumstances like the following: To a compound of two elements exhibit a third element; its combinative potency varies with the quantity and the relative saturation of the compound, or its being most remote possible from those of its separate components. Adding excess of the element, that is, more than its primary quantity, but some multiple, may separate the compound, and also keep soluble both the elements, and thus prevent any precipitate. Again, the compound may have one element in some multiple of its combinative potency, which may solicit or be solicited by the added element, and form a fresh compound, and yet leave a neutral compound, in character much different from the primary compound. Cream of tartar is not very soluble in water, and is a compound of potash with excess of tartaric acid. Dissolve some in water, and add some chalk; the excess of acid will solicit to combination part of the lime of the chalk, and

form a scarcely soluble compound. After this appropriation of part of the acid, the remaining neutral compound is very soluble, and has very different taste and properties from those of the cream of tartar.

The state of oxidation, also, of the acids and the metals much influences resulting phenomena. A determined state of oxidation is needful for the solution of metals in acids, and the acids themselves have combinative potency in the ratio of their state of acidification. Nitrous acid is superseded by acids weaker than the nitric; also sulphurous acid by others of inferior combinative potency to sulphuric acid.

The presence and the quantity of water is of much importance. Bismuth dissolves in nitric acid, yet on adding water precipitates. Mix solutions of muriate of lime and carbonate of soda; the two compounds separate, and fresh ones result—muriate of soda and carbonate of lime. Mix lime and muriate of soda with only water sufficient to form a paste, which submit to a current of carbonic acid gas; on the surface will be a saline efflorescence of carbonate of soda, and beneath will be muriate of lime in deliquescence.

The momenta of combinative potencies are in the ratio, not of the primary multiple, but of those of multiples thereof in the quantity employed, for quantity always compensates for weaker potency. Thus one acid with combinative potency less than another for a certain base, by additional quantity solicits and combines with a part of that base, from the acid with greater combinative potency, dividing

it between them in the compound ratio of their potency and quantity. This division of one substance between two others always follows the exhibition of three such with mutually energetic potencies. Hence, potency has most momentum when elements are first placed in contact, and this gradually diminishes in one or other as saturation approaches. Also, the great difficulty of the combinative potency of the added element completely separating or freeing a compound from the last portions of any component.

This is, probably, the real cause of difference in Analysis of the native minerals. Those of Vauquelin differ often from those of Rose, and both from those of Berzelius. The different analyses are useful for two purposes: they teach modesty in determining the precise proportions of components in the secondary compounds, and also, that to preclude, as far as possible, uncertainty in such researches there cannot be too great attention given in separating the compound, to ascertain which component had only one multiple of its combinative potency present; also, which had more, and how many more, than the primary multiple.

Again, hasty inferences and deductions have been made from the presence or absence of solubility of compounds at the temperature of the process pursued. Now, in solutions many separations ensue without any precipitate, which only results when the fresh compound, or liberated component, is partially or wholly insoluble in the liquid. Potash can be added to a dilute solution of sulphate of soda, without this latter precipitating, because of the great combina-

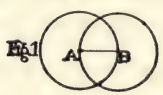
tive potency of potash for water. But with only a certain quantity of soda and of water to dissolve it, the fresh compound, sulphate of potash, partially soluble, precipitates, instead of remaining suspended; therefore, only very careful investigation of the results can prove the presence or absence of a precipitate. Sometimes all the components remain suspended, at others all precipitate together: to a solution of sulphate of iron add lime; this will be solicited to combination by a portion of the acid, and the resulting partially soluble sulphate of lime precipitates with the separated and less soluble oxide of iron. Frequently, on exhibiting another substance, there ensue, not separation of components, but equilibrium of momenta, and equivalence of the potencies. In water dissolve cream of tartar (supertartrate of potash), add soda and it will be solicited to combination by the excess of acid, and form a triple salt; likewise when to solution of perchloride or muriate of mercury we add ammonia.

For two bodies to chemically combine their components must have mutual momenta, and their elements reciprocal potencies; yet to any degree these may be affected by concomitant circumstances, as by multiples of one of the elements, by exhibiting a third substance, or by absence of the motions of heat, yet they all exist, though rendered sluggish. In the atmosphere the oxygen and nitrogen can chemically combine, yet their combinative potencies are sluggish, although exceeding the ponderance of their specific gravities; and the circumstances may be modified by the presence of hydrogen, carbonic acid, and other substances.

The combinative potency of a compound may be communicative, yet, exhibited to another, be *minus*, solicited to recipience, and separated; or be *plus*, and solicit as the agent, separating the other, and forming a fresh compound; or be *equal*, and both remain sluggish, with mere mixture, not chemical results. Hence, a compound, exhibited to an element, *plus* to each or one of the components, and to that of the active component for the receptive of the solicited compound, these separate, and two other compounds result, of the most communicative and least receptive elements, and of the solvent and the most receptive, the separated component.*

* In a new treatise on "Natural Philosophy," by Mr. Exley, are some mathematical demonstrations of the momenta and directions of Combinative Potencies, which I have *verbally* adapted to my own views, and trust I shall not be censured by persons fond of such analytical formulæ.

To determine the Combinative Potencies, communicative and receptive, of two components A B in a compound, mutually soliciting each other (Exley's *Principles*, Sect. II. Prop. 8):—

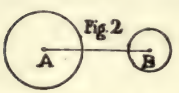


Let us assume that the two components are precisely equal (*Fig.* 1) in bulk, bb', and momentum, mm', their primary distance a, any other distance x, the space they traverse to combine s, and f the multiple of their potency at the distance x. Then,

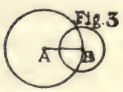
The combinative potency of A is to that of B as $\frac{m}{x^2}$, and that of B is to that of A as $\frac{m'}{x^2}$; m its momentum divided by the square of the multiple at the given distance; and that of B is similar; therefore, the whole potency when both have similar momentum, is $\frac{m+m'}{x^2}$; and when either is communicative and the other receptive, it is $\frac{m \infty m}{x^2}$; and $s = a \infty x$. Hence

$f\ d\ f = \frac{m + m'}{\infty\ x^2}\ d\ s$ and $f^2 = 2\ (m \underset{\infty}{+} m')\ \frac{a \infty x}{a\ x}$, or $f = \left\{2\ (m \underset{\infty}{+} m')\ \frac{a \infty x}{a\ x}\right\}^{\frac{1}{2}}$.

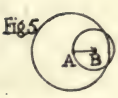
Also, as $m \underset{\infty}{+} m'$ is to m, so is f to the combinative potency of B $= \left(\frac{2m^2}{m \underset{\infty}{+} m'} \cdot \frac{a \infty x}{a\ x}\right)^{\frac{1}{2}}$; and that of A $= \left(\frac{2}{m \underset{\infty}{+} m'}, \frac{m'^2}{} \cdot \frac{a \infty x}{a\ x}\right)^{\frac{1}{2}}$; and consequently the momentum of A is to that of B as m' is to m, as by other ways may be easily determined. Hence the space traversed by A is to that traversed by B as m' is to m, allowing for a little variation of the circumstances because of the peculiar characters of the components.



While x exceeds b (Fig. 2.) the potency is communicative; but it is receptive when b exceeds x; in Fig. 4, A is the latter and B the former. With the components as 2, the potencies are equal; as 3, they vary, and A has more, or similar, or less momentum, as m' exceeds, equals, or fails m, till as 5, when excess of B commences, and continues, opposed, till A B again become as at first. The momentum being active or positive when communicative, and passive or negative when receptive. The momentum of A is constantly to that of B as m' is to m; and consequently each always equals that of the other at the same point in combinative potency and period of process.



When A B have equal bulks, placed as Fig. 1, their combinative potencies remain quiescent, by the momentum $\frac{m+m'}{b^2}$; because, only by excess of momentum in either can they be separated or more intimately combined. When their bulks are unequal, b exceeding b', their potencies remain quiescent when $m = m'$, and A B are as Figs. 3, 4, 5. Any additional momentum will move them either way, as 4; and by the least excess in either they will combine, as 3; but to separate them will require excess $= \frac{m + m'}{b^2}$ or $\frac{2m}{b^2}$; the converse will be as 5, where, in either, the least excess will separate them; but to combine them, the excess must $= \frac{2m}{b'^2}$.



When m exceeds m', the potencies are quiescent only as 3; to separate them, they must be as $\frac{m + m'}{b^2}$, to combine them, as $\frac{m - m'}{b^2}$; when m' exceeds m, they are quiescent only as 5, when they combine, when they are as $\frac{m' - m}{b^2}$, and separate when as $\frac{m' + m}{b'^2}$.

When both components are unsolicited, but have momenta through a determined distance, a the greatest, a' the least intervening distance, $r\ r'$ their radii with orbital spaces. In approximating (1) their momenta traversing from a to $r = \left\{2\left(m + m'\right)\frac{a - r}{a\ r}\right\}^{\frac{1}{2}}$. (2) The potency gained or lost from r to $r' = \left\{2\left(m \infty m'\right)\frac{r - r'}{r\ r'}\right\}^{\frac{1}{2}}$. (3) The potency lost from r' to a' is $\left\{2\left(m + m'\right)\frac{r' - a'}{r\ a'}\right\}^{\frac{1}{2}}$. The second case is one of neutralisation when $m = m'$, or $r = r'$, the potency remaining constant when $m = m'$, and the spaces being alike when $r = r'$.

Also the potency increases when m' exceeds m, and decreases when m exceeds m'; and the third case has the potency communicative, receptive, or quiescent, as the momentum lost in the second case fails, or exceeds, or equals, that gained in the first case.

And as the potency is indifferent or sluggish at the distance a', the hypothesis gives $\left\{(m + m')\frac{a - r}{a\ r} + (m' - m)\frac{r - r'}{r\ r} - (m + m')\frac{r - a}{r\ a'}\right\}^{\frac{1}{2}} = 0$.

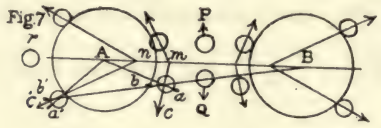
Therefore

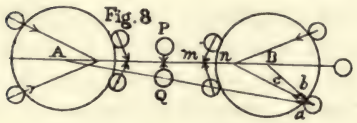
$$a = \frac{r'\ r'\ a}{2\ a'\ .\ \frac{m\ r' + m'\ r}{m + m'}} - r\ r', \text{ and } a' = \frac{r\ r\ a}{2\ a'\ .\ \frac{m\ r' + m'\ r}{m + m'}} - r\ r';$$

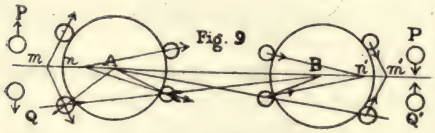
If $m = m'$, $a = \frac{r\ r'\ a'}{a'\ r' + a'\ r + r\ r'}$ and $a' = \frac{r\ r'\ a}{a\ r' + a\ r - r\ r'}$; and

If $r = r'$ $a = \frac{r\ a'}{2\ a' - r}$, and $a' = \frac{r\ a'}{2\ a - r}$.

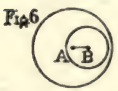
(2.) To demonstrate that two substances with similar combinative potencies do not chemically combine, but only when they are different. (*Ibid.*, Sect. VII. Phen. 84, 85):—







Suppose both A and B combinative in Fig. 7, or receptive in Fig. 8, or mutually communicative and receptive in Fig. 9. Suppose the short line *a* represents the momentum and direction of A towards a solicited substance, also similarly regarded by B, with the momentum *b*; and suppose the potencies would be efficient between *a* and *b*, with the direction *c*, precisely at some point *m* between the centres A B. The separate momentum of each, on the other side, is as *a'* *b'*, and the combined momenta in the direction *e'* from *n* also between A and B. Therefore the combined momenta of A and B soliciting any other substance nigh A, will be from points in A B between the centres A and B; and similarly will the combined momenta solicit a substance nigh B. The sum of the potencies is a momentum soliciting substances in the opposite positions precisely between the centres, and at right angles to the line joining those centres, as P Q, and for radii, in every way from that line as a centre. This situation of the patients by the mutual momenta proves that the compound momentum with the reaction affects both A B from a plane through P Q, at right angles to A B, and between the centres A and B.



When A and B are receptive (as Fig. 6.), attention to the direction of the darts, and repetition of the previous reasoning, will prove that similarly patients nigh A B are solicited *towards* points in A B, between the centres A and B, as before they were *from* them; and the requisite momentum with the re-action directed both ways, from a plane passing at right angles through P Q, affecting the patients, and likewise causing separation.

When A is communicative, and B receptive, as Fig. 9, then, by like reasoning and attention to the darts, the combined potencies of A and B with expanded orbital spaces towards points outside A and B, the reaction being from planes passing through P Q and P′ Q′ at right angles to A B produced ; hence the compound forces impel A B towards each other ; that is, they exhibit combination, on the same principles, as when alike communicative they exhibit separation. Were potency unappropriated, it must be without the circles, where the action is greatest, because the section of one is diminished by that of the other between them, which will promote the combination.

Hence results the accuracy of chemical determinations. Did the elements and their potencies, under the like conditions, ever vary, no two essays to produce the same compound could be relied on as efficient, whether by chemists of this or of any other country. But such is the certainty of the science that whoever weighs and combines 54 parts of nitric acid with 48 parts of potash, will obtain a result of precisely 102 parts of nitrate of potash (saltpetre) ; and every chemist knows that only this and no other result can possibly ensue. But was a person to properly weigh and combine 50 parts of dry carbonate of lime with 50 parts of acetic acid, and say that the result was 100 parts of acetate of lime—although in numbers 50 and 50 make 100—every chemist would know that the assertion is incorrect ; for 50 of carbonate of lime and 50 of acetic acid form only 78 of acetate of lime, in consequence of the carbonic acid evolving. Carbonate of lime is a compound of calcium 20 + 8 oxygen = 28 lime, or oxide of calcium, combined with 6 carbon + 16 oxygen = 22 carbonic acid = 50 carbonate of lime ; and in combination of the substances the acetic acid solicits the lime, and the 22 of carbonic acid is minus, leaving only 78, not 100, as the result of 50 and 50 chalk and acetic acid.

The importance of the subject being well-understood must be my apology (if any be deemed needful by my subscribers) for so fully stating these particulars, and in pursuing our investigations of the almost infinite variety of compounds, from the energies of these potencies, which we can prove, as far as our science goes, to be those only energetic for Nature's purposes, and in which we learn the wonderful and remarkable fact, that only very few elements occur together ; we are gratified and interested with those

proceedings which result from our own manipulations; although not the most attentive and skilful of these, and of current processes, suffice to accomplish like products with those which astonish us as produced on the most magnificent scale in the grand and vast laboratory of nature.

MANIPULATIVE PROCESSES FOR ANALYSIS.

In the following details great care has been exercised to fully and clearly particularise all the consecutive steps of the General and the Special Courses of Analysis adapted to supply the Manufacturer with accurate acquaintance with the behaviour of Re-agents with the components of each Material. This knowledge can be acquired only by experimenting; and the person who has sedulously regarded every change in the phenomena of a process—not seldom as sudden and unexpected as the turning of a vane—will have more correct and adequate ideas thereof, than he possibly can have who has several times heard them described, or read their description. So faithful is the evidence of which the eyes are made the medium of communication; for although there may be amazement, there cannot be deception.

By the manufacturer accustoming himself to manipulation, he will acquire dexterity in using his apparatus, and at pleasure pursue Analysis with facility, economy, and accuracy. Commencing with one experiment, he *must practise* all its manipulations in succession, however multifarious, in the best manner allowed by his opportunities and apparatus, fully to understand the whole. He must not indulge in the practice of some expert chemists, to trust to appearances, and because facts are well-known be careless and negligent to verify them. He must compare his own observations with what is

current, and revise any glaring difference by repetition of the processes. And the most attentive and minute investigation of his subject may be well compensated by the great satisfaction that would arise from the discovery of some new combinations, or unknown bodies. He must constantly register every new research; properly label and long keep each portion of the results, which he must often inspect, and notice any change in appearance; thereby the memory will be relieved, yet without incertitude of their nature whenever again inspected. By thus proceeding scarcely will it be possible for imposing and deceptive half successes to produce self-deception.

Analysis is the general term for the Processes of Chemistry, whether determinative or productive. But it is divided into *Analysis*, or separation, and *Synthesis*, or combination, as scarcely ever does the former ensue unaccompanied by the latter.

Analysis presents alone and distinct from each other the component elements of a substance, and determines their kind, nature, weight, combinative potency, and relative quantities or definite proportions; also the phenomena when separating. And Synthesis exhibits their distinctive characters when becoming components of fresh compounds in characters different from every other, although uniform in the smallest portion. Neither of these, however, develops the nature of the ultimate cause of these effects and results, nor renders obvious the intervention of the disjoined state which must necessarily have occurred. To be completely successful in producing simplicity of effect and certainty of results,

we may apply the most particular knowledge of the ascertained properties of bodies, and also employ different *pure* substances, because of their use called *re-agents.*

In every instance of the annexed details there is absolute necessity for unremitted *cleanliness*, as thereon often may depend most important results. For this purpose it is proper to keep ready at hand a towel, ewer of water, two bowls, a sponge, silk and linen rags, tow, rods of whalebone, plain and capped with sponge. Dirt of any kind is removed more easily at first than when left to attach to an article of apparatus ; therefore immediately must be washed every glass vessel when emptied of its contents, when there is least danger of breaking them. If phials, shake well in them a few bits of raw potatoes ; with the whalebone rod and sponge cleanse the corners, and tubes, then *immerse in pure water*, and place away for use. When oil or resinous fluids have been used, rinse first with dilute sulphuric acid or solution of potash, prior to using the potatoes. Hereby will be prevented the unpleasantness of having to cleanse a vessel at the moment when its use might facilitate, perhaps complete, an important process, and the consequent failure, and possible sacrifice of time, labour and funds. Although at commencement, when the mind is much engaged, the trouble to cleanse and replace each utensil the instant it is empty may be irksome and seem fastidious, yet it most amply repays by freedom from anxiety of its being ready for use, and by saving time except what is just required for gently wiping off the dust with the silk or linen rag. Every other kind of

utensil, as soon as its need ceases, must be cleaned and replaced; and time will be saved by—"a place for everything, and everything in its place."

To the re-agents the name *Tests* is also applied, and *Testing* is the exhibition of a test to a compound or solution. Each test so employed, whenever active, causes a precipitate, white or coloured; it likewise in a peculiar manner solicits the components of Salts, which are conjectured and determined from comparing the effects of different tests on the same solution. Their nature and utility are developed in the analytic processes. Their names are the following, in alphabetical succession:—

Acid, Acetic, solicits to combination, metallic tin, iron, zinc, copper, nickel, and the oxides of many other metals, when a solution of the sulphate of any is mixed with a solution of acetate of lead. With magnesia it forms a viscid compound, but it has very trifling combinative potency with alumine. The most ready way of procuring it very strong is to expose good vinegar to a freezing mixture; to abstract the crystals, cast them on a coarse rag in a funnel for the acid to drain off; and when pure, it is changeless by gallic acid, sulphate of soda, hydrosulphurets, and sulphuretted hydrogen.

Acid, Boracic, a compound of boron and oxygen (B^2 0=6), is of much utility as a flux for the blow-pipe assay, as the highest temperature does not volatilise it, neither do the compounds it forms with minerals sink into the pores of the charcoal support. Only the phosphoric acid remains in combination efficiently opposing its soliciting the base; all others separate from bases on boracic acid

being present. Silicates are readily fusible with it, and earthy compounds fuse into a limpid paste. Davy first recommended its adoption to discover a fixed alkali in minerals. It oxidates or separates metallic iron, zinc, and copper, and it solicits to combination most metallic oxides, also the alkalies and the earths, the colour of the compound formed with metallic oxides, etc., suggesting the probable nature of the substance under examination. The greater number of its combinations have had only partial attention paid to their properties. (See the Chapters on ACIDS and ALKALIES, also on GLAZES.)

Acid, Muriatic (or *hydrochloric*, equal volumes of chlorine and hydrogen), as formerly prepared (from 1 part common salt and 10 parts dried clay, well ground into a stiff paste, then put into a stone-ware retort, and by a reverberatory furnace heat, distilled over and collected), presented an excellent example of combinative potency in the silica of the clay soliciting to combination the alkali of the salt, and forming a clear and durable glass. This might have suggested an explanation of the action of the salt in the glazing of the *Crouch Ware*. This acid is of general use as a solvent, besides its value as a re-agent. It causes a dense cloud whenever ammonia is present. It precipitates silver and lead, white, in aciduline solutions, but that of silver soon becomes black in the solar ray; is soluble in ammonia but insoluble in water; that of lead continues white, is soluble in 22 parts water at 60° Fahrenheit, and in dilute nitric acid. It also discovers manganese in minerals, thus—"the powder investigated,

moisten with muriatic acid, gently heat, and chlorine evolves when manganese is present; in a platinum spoon melt soda or borax, add the powder, keep it melted in the *inner* flame of the lamp, the red colour will gradually diminish, but will reappear in the *outer* flame, or on adding nitre, when it is manganese."—(*Ann. Phil.*, 1814.) When in company with metallic tin, zinc, or potassium, by them is its chlorine solicited to combination, a chloride of each being the result, and liberating the hydrogen.

Acid, Nitric (equal volumes of hydrogen and nitrogen, and three of oxygen), is much employed as a solvent, because of the facility with which the oxygen is separated, and the oxidated metals dissolved. In its concentrated state it is employed to determine whether tin is pure or alloyed with copper; and much diluted, to distinguish steel by a black spot, from iron by one greyish. It detects nitrogen in animal substances, resin and starch in vegetable substances, and uric acid in urine.

Acid, Oxalic, because of its greater combinative potency with lime than with any of the other bases, and separating it from all the other acids (unless present in excess), is the most ready detector of the presence of lime in liquids, forming a pulverulent insoluble salt, only by fire decomposable. In like manner it dissolves alumine, and when again by fire the acid evolves, intumescence ensues. Its combinative potency is less with metallic iron, lead, tin, zinc, and antimony than in forming triple salts with most of the metallic oxides, also ammonia, soda, barytes and magnesia. In solutions it separates

iron oxide from that of titanium, and in a boiling solution of it the oxide of iron dissolves, and that of cerium remains as a white powder.

The crystals of this acid, and the salts also employed, must be *carefully purified* by this process: In distilled water dissolve the crystals, then filter the liquid; the water present keeps the particles asunder; by suitable gentle heat evaporate a portion of the water till the particles appear to commence solidifying, as by the pellicle or film seen on the surface; place the vessel on some folded paper to repose twenty-four hours, remove the crystals and carefully preserve from air between blotting-paper; repeat the evaporation and crystallisation until all readily procurable are obtained.

The solution for testing should always be prepared in a vessel with much larger capacity than the mere quantity needed to preclude loss from effervescence, or expansion of the mass by chemical action; and it should resist the action of the solution, whether aciduline, alkaline, or aqueous. In this vessel agitate the fine powder of the salt among the liquid with an earthenware or glass rod, and when all is mixed (as the solution is needed, *saturated* or holding, at a known temperature, all it possibly can; or *diluted* with only a portion present), place a filter in a funnel with the neck entering the phial, and carefully decant the liquid, and closely stop when filtered. The solution may require heat or cold, yet without chemical action, the characters and properties of the components remaining after evaporation; but with chemical action it is a fresh substance,

wholly different from those of either component separate, or of both merely mixed.

Acid, Sulphuric, is so combinative that a single drop in a very large bowl of water will give a red tinge to litmus paper. In its concentrated state, sp. gr. 1·845, it has an oily consistence without colour or odour. It determines the presence of other acids, also of lead, mercury, barytes, strontia, and also lime with certain bases. When accompanied by several of the metals at a high temperature, they solicit a portion of the oxygen to form oxides, which combine with the remainder of the acid during the evolving of the sulphurous acid gas.

Acid, Tartaric, solicits to combination alkaline, earthy, and metallic bases, as tartrates, and is employed to ascertain whether the alkali present in a liquid is potash or soda, as the salt formed with the former is very soluble, with the latter insoluble in water. The solution is first concentrated, and then excess of solution of tartaric acid is added; when the alkali present is potash, there is a crystalline precipitate, when it is soda, the mixture continues clear, and seems unaffected. The crystals should be dissolved *only* when to be *instantly* employed.

Ammonia, Liquid Caustic, is of general use to neutralise aciduline solutions of bases, when potash or soda would be improper. It is a compound of 3 volumes hydrogen and 1 volume nitrogen, with a sp. gr. of 0·590, air being 1·000. The only metal which it solicits to combination is zinc, which is first oxidated and then dissolved, but it is equally

potent on the protoxide and peroxide of copper, the oxide of silver, the third and fourth oxides of antimony, very rapidly, but sluggishly on the oxide of tellurium, protoxides of nickel, cobalt, iron, and peroxides of tin, mercury, gold and platinum; the three last, with silver, being fulminative. With the salts of the earths and metallic oxides it forms triple salts; thus when the compound is sulphates of magnesia, lime and iron, with ammonia neutralise any excess of acid, add succinate of ammonia, and any peroxide of iron present will precipitate, leaving the earths in solution. Or, the solution evaporate dry, just incandesce 60 to 80 minutes, which will decompose the sulphate of iron, leaving the sulphate of lime insoluble, and the sulphate of magnesia soluble in the water employed to digest the calc. Of course, when only the first and the last are present, whatever is insoluble will be oxide of iron. When copper or nickel is present in a solution, ammonia produces a clear sapphire blue colour. In the liquid immerse a bar of zinc, or clean knife-blade, and copper, but not nickel, will precipitate. With a little ammonia, zinc precipitates white; but this is re-dissolved by *plus* of the alkali. When the solution has the alkaline earths present, with alumine, all of them precipitate on adding ammonia; when only lime and magnesia are present, it partially precipitates the latter, but not the lime. When carbonic acid is present, free, or united with magnesia, ammonia solicits to combination part of the excess of carbonic acid from the magnesia, and the fresh-formed carbonate of ammonia precipitates carbonate of lime, and also salts of alumine. Ammonia

separates iron from manganese thus: Dissolve the pulverised mineral in muriatic acid, dilute much with pure water, add ammonia till the litmus paper, just *red* by vinegar, becomes blue, leave to repose 24 hours; filter out the oxide of iron, the solution evaporate dry, by incandescence expel the muriate of ammonia, throw on a filter the oxide of manganese, and wash well.

Ammonia, Benzoate of.—In pure water dissolve carbonate of ammonia, and add benzoic acid till the solution is neutral—or, to this solution, boiling, add excess of gum benzoin—next, filter, evaporate and crystallise. This re-agent separates iron from all earthy salts, also from nickel, cobalt, zinc, and many other metals; thus by ammonia neutralise the aciduline solution, add much pure water, then *drop* in the solution of the test while there is any precipitate; this filter out, wash well with cold water, dry at 212°, digest in ammonia 12 hours, filter out, and then wash well the red oxide of iron; the solution evaporate, to recover the benzoate remaining. It separates iron from manganese in solution; thus by any alkali neutralise the aciduline solution, then gradually add this re-agent while there is any precipitate; all the iron falls, all the manganese remains in solution. When earths also are present, again acidulate the solution, and boil, to render inert any benzoic acid present.

Ammonia, Carbonate of (like other carbonates of the alkalies), precipitates most earthy and all metallic salts in solutions, the respective colours suggesting the bases. When copper is present the solution has a blue colour. With phosphate of soda

this re-agent detects and separates magnesia from the other earths present, and dissolves yttria, glucina, and zirconia, whenever present in the solution.

Ammonia, Ferrocyanate of, is used solely with solutions of salts. When they are of the metals, or (neutral) of the alkalies, ferrocyanate of potash would separate the former, yet not determine the previous presence or absence of the latter; but this re-agent precludes incertitude by precipitating the former, and the carbonate of ammonia the latter (the solution being raised to a temperature above 180° to separate the magnesian salts). Filter, evaporate dry, incandesce to expel the ammoniacal salts, and leave free the yttria, glucina, and zirconia possibly present. The calc boil in pure water, filter, and evaporate for the alkaline salts. To determine whether ammonia be (or not) present prior to solution, add a little potash to the powder or salt, and ammonia will evolve if present.

Ammonia, Muriate of, will detect alkalies and alkaline earths, by which it is separated; or, when the salt is dry, by a moderate heat decomposed, and the ammonia rendered sensitive. But, because in this state, it is decomposed by many metals and metallic oxides; by other re-agents we determine the presence or absence of alkali or alkaline earth. When alumine is present in alkaline solutions, on exhibiting this re-agent the alkali is solicited to combination by the muriatic acid, the sp. gr. of the liquid is altered by the free ammonia, and the alumine precipitates and must be filtered out, well washed, and dried at 350°, then be preserved for occasional use. It detects platinum, by a precipitate, bright yellow,

when pure; orange, when irridium is present; the compound (of oxide of platinum, ammonia, and muriatic acid), subjected to very high temperature, is decomposed; chlorine and muriate of ammonia evolve, leaving spongy metallic platinum. The hydrostatic test, or specific gravity, fails to verify when gold has been adulterated by platinum, but the aciduline solution treat with green sulphate of iron in solution to precipitate the gold, and by this re-agent find the platinum.

Ammonia, Oxalate of, detects the most minute portion of lime present, even to the twenty-four thousandth part in water, when the solution has its mineral acid accurately neutralised by an alkali (proved by restoring to blue the litmus paper made red by vinegar) or is freed from barytes or strontia by sulphuric acid. This re-agent also precipitates magnesia during twenty-four hours' repose.

Ammonia, Succinate of (also, of *Soda*), carefully *dropped* into a solution detects (not protoxide but) peroxide of iron, separates the oxides of iron and manganese, and in slightly aciduline solutions precipitates alumine, glucina, and zirconia.

Ammoniacal Sulphate of Copper.—With blue vitriol (or sulphate of copper) saturate liquid ammonia, and employ the compound to discover arsenic in any solution or liquid. The yellowish green precipitate is soluble in ammonia and most acids, but not in water, and must be dried and reduced with the *black* flux to determine the presence of metallic arsenic. The charcoal of the black flux (nitre 1 + supertartrate of potash 2, detonated) solicits to combination the oxygen of the white oxide, and as

carbonic acid gas evolves, while the further separation is promoted by the alkali and excited combustion, leaving the arsenic in its metallic state. The process, carefully conducted, alleviates the weariness of persevering attention by the suitable and pleasant manner in which the mind acquires correct information how substances either combine or separate, and reciprocally produce results in accordance with certain principles.

Arsenious Acid (or white arsenic) will detect lime in solution by a white precipitate, which is soluble in excess of the re-agent. And when present in only one hundred thousandth part of the solution will form with sulphuretted hydrogen, or hydrosulphuretted solutions, a beautiful golden yellow precipitate of sulphuret of arsenic. This, filter out, wash, dry, and place in a test-tube with a bit of caustic potash; in the flame of the blow-pipe lamp decomposition ensues, the sulphuret of potash is at the bottom, and on the sides sublimes the metallic arsenic, with steel-bright lustre. This acid solicits to combination all the pure alkalies and alkaline earths; the arsenites of potash, soda, and ammonia are soluble and not crystallisable, but scarcely soluble are those of lime, barytes, strontia, and magnesia. The golden yellow precipitate by the hydrosulphurets of alkalies results readily when the arsenious solution is previously treated with a drop or two of nitric or muriatic acid. The peculiar yellow precipitate by nitrate of silver would be re-dissolved by nitric acid if this be left unsolicited by a few drops of ammonia, yet only a few must be used, else the like result will ensue. A beautiful and very distinctive grass-green

precipitate is formed with diluted ammoniacal sulphate of copper, which, well washed, is rendered brownish-red by sulphuretted hydrogen water, blood-red by ferrocyanate of potash, and yellow arsenite by nitrate of silver.

Barytes-water.—By very high temperature decompose the nitrate of barytes, or with like temperature decompose a mixture of sulphate of barytes with carbonate of potash, and incandesce the resulting carbonate. The caustic barytes thus obtained dissolve in pure water to saturation. This readily detects either carbonic or sulphuric acid, however present, the precipitate of the former being soluble, that of the latter insoluble, in dilute nitric or muriatic acid.

Barytes, Acetate of, is very useful to determine which, and how much, alkali or alkaline sulphate is present in a solution.

Barytes, Muriate of, detects sulphuric acid, free or combined, the precipitate being soluble in concentrated acids, but scarcely in pure water, hence can be fully obtained. When alkaline carbonates are present, a few drops of muriatic acid is exhibited to prevent this re-agent being inert. And when the muriatic acid of this test might embarrass the determinations of the analysis, we use *Nitrate of Barytes.*

Cobalt, Nitrate of.—In nitric acid dissolve cobalt, metal, or oxide, then evaporate to the needed strength. With a concentrated solution just moisten the mineral fine powder, and on platinum foil submit it to the white flame of the blow-pipe, and when alumine is more plentiful than iron or other colorific oxide, soon is seen a blue assay, more or less brilliant

and intense, as the alumine is pure and in excess. Gahn says—this is *infallible.*

Copper, Sulphate of, by a bright yellowish-green precipitate also detects arsenic in solutions treated with a small portion of alkaline carbonate; also sulphuretted hydrogen by a dark brown precipitate of sulphuret of copper.

Gold, Muriate of, detects the presence of tin at its minimum of oxidation.

Iron, polished, as wire, bar, or plate, solicits to combination, or separates from aciduline solutions, copper, antimony, and tellurium in the metallic state.

Iron, Protosulphate of, solicits the oxygen from gold and palladium in aciduline solutions, leaving the metals to precipitate. It also detects oxygen in any water where it is present by a brownish precipitate, and gallic acid by one which becomes black when exposed to the atmosphere.

Lead, Acetate of, a most useful detector of sulphuretted hydrogen, or hydrosulphurets, by a black precipitate. It also detects muriatic and sulphuric acids by a white precipitate, the former soluble, the latter not, in dilute nitric and acetic acids, and by a white precipitate likewise phosphoric acid, proved by the blow-pipe.

Lime, Muriate of, is occasionally employed to detect alkaline carbonates, by which it is separated, and left as carbonate of lime. This is also used, when its water is dissipated, as chloride of calcium, to abstract water where its presence would be deleterious.

Mercury, (also *Silver-leaf*), by losing the previous

brilliance detects the presence of the most minute portions of sulphuretted hydrogen gas or hydro-sulphurets of the alkalies (in mineral waters especially).

Mercury Protonitrate of, detects the one thirty thousandth part of free ammonia in water by a blackish-yellow tint, and when in plenty by dark grey or black precipitate; sulphuric acid by a white crystalline precipitate, which repeated affusion with boiling water renders yellow; also muriatic acid and phosphoric acid (when neither alkali nor alkaline earth is present) by a white precipitate; the former soluble, the latter not, in nitric acid. It gives, with muriate of gold, a dense bluish-black precipitate, and orange coloured, with muriate of platinum.

Mercury, Cyanuret of, detects palladium by a yellowish-white precipitate, fulminative by raised temperature.

Mercury, Perchloride of, (always kept in a covered phial) detects alkalies, alkaline earths, and ammoniacal salts—the caustic alkalies by a yellow, the carbonated alkalies by an orange-coloured precipitate.

Platinum, Muriate of, by a yellow precipitate (bichloride of platinum and chloride of potassium) distinguishes salts of potash from those of soda, which it does not affect, in solutions concentrated but without excess of acid. It also detects the presence of lime.

Potash, Ferrocyanate (triple Prussiate) *of*, by the colours of the precipitates detects the presence of certain metallic oxides. With the protoxide of iron the precipitate is white, but soon becomes blue in the

air, and with peroxide it is Prussian blue. The earths are very sluggish to its action.

Silver, Acetate of, is used to determine nitrates and muriates whenever employing nitrate of silver might embarrass the analysis by additional nitric acid. Also more readily to discriminate the alkali of a muriate by evaporating dry the liquid treated with acetate of silver, then re-dissolving the dry mass in alcohol, and again evaporating dry; a deliquescent salt will indicate potash, and an efflorescent salt will indicate soda. The test must be kept in a covered phial.

Silver, Nitrate of.—To pure water 50 parts, and concentrated nitric acid 25 parts, add 25 parts of grain silver, or silver-leaf, and keep in a sand-heat till dissolved; then by more heat evaporate to the needed concentration for use, and preserve in a covered phial. This re-agent, by a white curdy precipitate, rendered black by the solar rays, soluble in ammonia but not in water or nitric acid, readily detects chlorine and muriatic acid, whether free or combined; and a grain of common salt in 42,250 grains (more than 5 pounds) of pure water is recovered in white clouds, yet only is the muriatic acid the $\frac{1}{103333}$ part of the water. The presence of sulphuretted hydrogen and hydrosulphurets is indicated by a black precipitate of sulphuret of silver; chromic acid by a red carmine precipitate of chromate; arsenic by a yellow arsenite—nitrate or acetate of barytes being previously introduced to remove sulphuric and sulphurous acids, and nitric acid to saturate any carbonated alkali. The precipitated carbonate of silver, by using alkaline carbonates, is

soluble with effervescence in dilute nitric acid, but not that by using muriatic acid.

Silver, Sulphate of.—Solution of nitrate of silver treat with *plus* of sulphuric acid, filter out the precipitate, wash till the litmus-paper is not altered; in distilled water boil the precipitate, cool, filter, concentrate to the required strength, and preserve in a covered and well-stoppered phial. It best detects muriatic acid where nitrate of silver might suffer from the presence of sulphurous or sulphuric acid.

Soda, Borate of (*or Borax*), in its native state, called *Tincal,* is found in the East Indies and in South America, and is purified by long boiling in plenty of water, which after being filtered is left to crystallise. Boiling-water dissolves one-sixth, cold one-eighteenth, of its weight. In this state it is called common borax. When heated it intumesces, loses its water of crystallisation, becomes white, porous, opaque, or *calcined* borax; and by a stronger heat it fuses into a greenish-yellow vitreous and transparent substance, or *glass of borax,* soluble in water and efflorescent in air. Some have supposed the alkali more than triple the quantity needed to saturate the boracic acid; others that it is Sodium 1, + B. A. 5, + Ox. 3. In the analysis of minerals glass of borax readily causes fusion of those which are sluggish with alkalies; and borax in its several states is an excellent flux for earthy substances and metallic oxides.

Soda, Phosphate of, is used with bicarbonate of ammonia to separate magnesia in solutions; also, when free from the water of crystallisation, as a flux in the blow-pipe assays, being more easily managed

than the microcosmic salt (phosphate of soda and ammonia,) and promoting the fusion of earthy substances and metallic oxides.

Soda, Sulphate of (*or of Potash*), is the best re-agent to detect the presence of lead. The white precipitate is soluble in warm diluted nitric acid, but not in water or ammonia, and is rendered black by sulphuretted hydrogen-water, thus distinguishing lead from barytes.

Tin, Protomuriate of, detects the presence of gold by a fine purple precipitate (*the Purple of Cassius*); of platinum by one orange-coloured; of perchloride of mercury (corrosive sublimate) by a dark brown; of palladium by one similar, but by excess of the test the solution has a fine emerald-green transparency.

Zinc may be employed to separate, in solutions which have scarcely any excess of free acid present, metallic copper, lead, tin, silver, and tellurium; and also lead, tin, copper, and tungsten, from their alkaline solutions. But care is needed to prevent a portion of the zinc precipitating as an oxide, or an alloy.

Zinc, Hydriodate of.—In distilled water digest equal weights of scales of iodine and zinc filings twenty-four hours; filter and keep well-covered. This fresh re-agent gives to the salts of most metals by it precipitated from neutral solutions distinctive colours, equally with sulphuretted hydrogen, hydrosulphurets, and ferrocyanate of potash. The precipitate of nitrate of silver is yellowish-white; muriate of platinum deep brown-red; nitrate of mercury, dull orange; muriate of mercury, dull brown;

nitrate of lead, bright lemon; muriate of bismuth, grey; nitrate of bismuth, chocolate; muriate of antimony, black; nitrate of antimony, first orange; well-mixed, black; muriate of nickel, black; nitrate of nickel, light yellowish-brown; muriate of copper, greenish-cream colour; acetate of copper, dirty light olive-green; muriate of tellurium, rhubarb colour.

The following has been announced as *a precipitant of all metals:* In pure water dissolve sulphuret of lime; filter free from atmospheric air, concentrate the solution, and keep well-secured from the air. The solution may be evaporated and crystallised till all is obtained, and the crystals must be kept secured from the action of the atmosphere.

The solutions, or supernatant liquids, and some of the results may seem of trifling value; but it may always be worth while to carefully decant into small covered jars all sorts, and place each aside; wipe clean the outside, label the contents, numbered to agree with the registered details, and frequently inspect during all the time they are preserved, and carefully register whatever changes appear. Many grand discoveries of the science were suggested by phenomena of long-retained results: which would not have rewarded the perseverance of those to whom we owe them had the label been neglected, or the different phenomena disregarded, or the liquids hastily cast away as valueless.

PULVERISATION.

When a substance is submitted for analysis, it is proper to notice its induration, or pulverulence, specific gravity, hardness, texture, scintillation with steel, result under the nail, crystal or hard stone, permeate by light, homogeneous, or heterogeneous character. Next prove, First, its accession or diminution of weight, also its being soluble or not in water, by boiling or digesting; Second, whether *en masse*, or in powder, it yields to acids, effervescing, or to solution of caustic potash; Third, whether it detonates or not with nitre; Fourth, what results when distilled with sulphuric acid or potash; Fifth, what phenomena appear under the blow-pipe, alone, or with soda, borax, or mic. salt, on charcoal or platinum foil; also whether it decrepitates on gradual rise of temperature.

When a stone that scintillates with steel fuses *alone*, we know that there are present lime, or calcareous earth, and silica; with another, either alumine or magnesia (by a few supposed a modification of lime), and probably a metallic oxide, iron, manganese, nickel, copper, and chrome.

When the mineral is hard, and requires to be pulverised, it is proper to weigh a small portion, place in a covered platinum crucible, raise to a white heat or bright incandescence, and weigh to determine its loss or gain by the heating; then throw it into cold water to render it brittle and easily pulverised; again weigh, and register any difference should

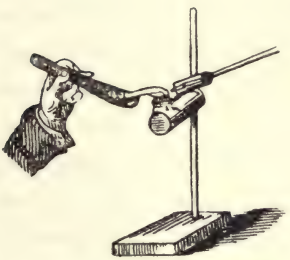
volatile elements evolve. Wrap in paper, and with a hammer and a smart, hard stroke, crush or break it.

When not needed to be very comminute, in a Wedgwood's mortar (No. 2, 3 inches wide, and 1½ deep), by a dexterous motion of the pestle round the sides, triturate or rub the mineral till its primary colour is entirely changed, from being dry appears moist, retains any impression of the spatula, and is not gritty rubbed between the thumb and finger (this however causes loss), and can be readily taken out by a spatula of glazed card. For small quantities of salts, this mortar and process will be found most useful. When not restricted to the exact quantity, the soluble fine powders may be passed through a lawn sieve, and the insoluble washed over, as subsequently directed.

When the powder must be very fine, on a porphyry slab with a muller, or in a flint or agate mortar with a pestle, rub or levigate in water, till proper for the purpose, keeping the mass in the centre of the slab by means of a clean cut card, bone folder, or palette knife. Powders of different comminution are obtained thus : mix the substance in water, let it repose two minutes, and decant into a bowl ; add more water to the first mass, agitate well, wait a minute, and decant into another bowl ; repeat the process twice or thrice more ; the finer the powder, the longer will it remain suspended in the water ; and to obtain this for qualitative analysis, evaporate the water slowly. After the powder is dried and weighed, any increase of weight will be from abrasion of the mortar, and must be taken into the account.

THE BLOW-PIPE ANALYSIS.

THE blow-pipe is now become indispensable to analytic chemistry, and its use cannot be too soon carefully acquired and steadily practised. Its advantages are numerous and incalculable in the detection of fixed bases, and in the formation of useful glass articles of apparatus. The figure in the margin shows how it must be used, and also the method of holding it properly.



The word *Base* strictly signifies that elementary component of a compound, whether alkali, earth, or metal, which solicits, or is solicited, to combination with the other elementary component, and from whose combinative potency there are definite results, in accordance with the nature of the components and the condition of their combination. But it has been extended, not philosophically, to indicate those substances which when in atmospheric air are united to oxygen, etc., form compounds, as though it supplied the distinctive properties, which, in fact, result from the combination, and the qualities which depend as much on the state of combination as on the nature of the component.

The blow-pipe employed for chemical and mineralogical purposes, whether formed of brass,

tin-plate, silver, platinum, or glass, is varied in length according to the sight of the operator, as it must allow the substance (usually called the ASSAY), when subjected to the flame, to be only at that distance most distinctly and clearly perceptible by the eye, and which is from six to eight inches. The mouth-piece is flattened or oval, and frequently formed of ivory; at some part of the tube is a bowl, or enlargement, wherein the vapour of the breath condenses and remains in moisture; and movable nozzles for a stronger or finer blast, with each aperture truly round and smooth, and in different sizes.

There are several compound blow-pipes constructed to be supplied with air from bladders, or reservoirs, filled by the mouth at intervals; others are supplied by a pair of double-bellows fixed beneath a table, or by equivalent contrivances; and others are adapted to consume mixed gases from gas-holders, bladders, or reservoirs, or only mixed before effluxion at the fine jet, to preclude explosion.

Each of the COMPOUND BLOW-PIPES called Gurney's, Brooke's, Tilley's, Clarke's and Toft's (cheapest) has its peculiar advantages in using, but is expensive to a person of limited income. That which I employ costs very little, because the more expensive parts, *taps*, are useful in other processes. I have a piece which by a screw is fixed to a table. The piece is perforated, and tapped for screws on its upper and under surfaces; likewise on the outer and two sides. Into the top I screw a cock-spur gas-tap, to which I have three jets of different-sized perforations, also an extra piece filled with fine loose iron filings, for insertion betwixt the pipe and jet when

consuming gas. Into the lowest aperture I screw my tap, connected with a reservoir (bladder, or elastic gum cloth), and likewise screw taps into the two sides. The outer hole admits to have screwed into it an angular piece with a valve at the end inserted, and into the other end of this screws a blow-pipe, by which I can fill my reservoir at convenience. Thus either one or more bladders can be attached, with distinct or mixed gases, at pleasure ; or only common air can be used, as the occasion may require. At present, I have not had the disaster of an explosion ; neither do I expect it, as each gas mixes with the other only just when expelled from the pipe.

But instead of bladders we can employ Indian rubber bottles, prepared thus : Very black, large, even bottles, first are immersed fifteen to twenty minutes in boiling water, then cooled ; on the flanged end of the tap the neck of the bottle is carefully tied by a waxed string ; the air (or the gas) is condensed into the bottle. At first a blister appears, and gradually enlarges till the bottle has all like thickness ; then the condensation ceases, the tap is stopped, and can be affixed to the table-piece. Two of these bottles of atmospheric air will serve an hour, and of gas much longer. And by using the double (or T) connector of gas fittings, the supply may be continued *ad libitum* without disturbing the process. And not the least surprising part of the affair is the fact that when oxygen and hydrogen are condensed together in the exact proportions which when detonated form water, and the mixture is through a pipe and fine jet directed upon the flame of a lamp (forming the oxy-hydrogen blow-pipe), we readily

obtain not previously imagined degrees of heat, whose potency has subdued the most refractory substances.

When the simple blow-pipe is used, a candle of tallow, or of wax, with a thicker wick than common is employed to supply the flame. Convenience is the first object, and this is so; but the radiant heat of the assay so soon melts the wax or tallow, and causes the wick to consume so quickly, that even the trouble of snuffing is a drawback in important processes. I find a lamp made with a beak into which the wick is held by a wire collar, and over which a hood can be readily placed, very useful; the wick is of soft cotton roving, clean, dry, and scarcely twisted, and olive oil is best, but purified rape oil and hog's lard will be found the only proper substitutes. The oils should be kept corked when not in the lamp, and the wick must be destroyed. This lamp will answer all purposes of the operator, with the compound blow-pipe, when gas is not used; and the bright clear flame, devoid of smoke, can be managed most advantageously.

With the blow-pipe and lamp, or candle, the operator may effect an assay with heat more ardent than that of a furnace. In a few minutes he can ascertain the general nature and properties of even the most valuable mineral, or chemical compound, by the minutest portion thereof, in reference to fire; and, free from the uncertain conjecture of what occurs in the centre of a furnace, wherein such an experiment might be made on a large scale, he can witness the commencement and the conclusion of all the appearances and their proximate causes, the

chemical or the mechanical mixture or conglomeration of the components, and ascertain and determine results, which else would require large furnaces, great quantities of substances, cumbrous apparatus, and many hours of attentive investigation. The only drawback on its excellence is its not determining the proportions of the components.

With the simple blow-pipe most readily, and with least fatigue to *blow*, so that the stream of air may flow uninterruptedly against the flame during the continuance of the experiment, even when that is occasionally several minutes, the operator must attend to these particulars: First acquire the practice of breathing through the nose while the tongue touches the roof of the mouth, and the lips are closed; this will probably be affected in from ten to forty minutes. The muscles of the mouth will soon conform to this fresh kind of exertion. Next, breathe through the nostrils, and yet keep the cheeks distended with air all the time; afterwards inspire several supplies of air while the cheeks are filled; and at length, with the cheeks full, easily compress them, and let the air flow through the pipe, even while inhaling a supply by the nostrils, keeping the tongue to the roof, unless when instantly supplying air from the lungs. The lips will be subject to lassitude on the first trials, but determined perseverance is requisite, and with this the operator will successfully blow for any length of time with only little inconvenience.

The next important remark is, that wherever the operator wishes to most readily effect his object, he must be secure from any current or draught of

air, that his exertions may not be unnecessarily lengthened. And also, that there is no subject he may possess but will be worse for violent blowing, and rarely is any refractory to continued moderate exertions.

Let the wick of the lamp, or candle, be a little bent, or the candle oblique. Direct the stream of air from the pipe along the wick, but without striking the flame, and notice that when the aperture is too large an irregular cone will be formed, and when it is not round and smooth, the cone will be ragged or rough. But when the orifice is proper, the cone will have an inner portion, light blue, pointed, and an inch long—this point has the most intense power—and an outer portion, vague, brown, varied in length, and with diminished power. By the former, carried brilliantly and equally on all parts of the assay, which *never needs to be larger than a grain of mustard seed,* the operator can *reduce* or *de-oxidate;* and by the outer, all the combustible particles will quickly be saturated with oxygen, and the substance be *oxidated,* not acidified. A small bit of grain tin is useful to ascertain the reducing flame, and the degree of exertion needful to keep it reddish-white on charcoal.

Dr. Farrady says, the aperture of a blow-pipe should be the fortieth or fiftieth of an inch diameter. The jet end may be platinum. The mouth and cheeks should act independently of respiration by the nostrils, so as to maintain a constant current. Success depends on knack and practice. For ordinary purposes a tallow or wax candle, or lamp wick, are sufficient, but for great heats broad flat wicks, are

used. The blast should be directed a little above the wick, and from a candle inclined a little upwards to prevent guttering. The greatest of the blow-pipe flame is at the extremity of the blue cone, where the combustion is complete, that is, where the hydrogen and carbon of the wick are in equilibrium with the oxygen, and fix its maximum quantity. There should be neither flame nor smoke at the extremity. When oxygen gas, from a caoutchouc bag or vessel, is urged through the pipe, the heat is the greatest known to art. Sometimes condensed oxygen is forced into vessels, and a strain produced by opening a cock. Hydrogen, too, has been used with oxygen instead of lamps, and the effect is more powerful, but attended with danger of explosion. The substance should be fixed on sound charcoal, or in a platina spoon, or on white clay. With oxygen and hydrogen platinum runs in drops, and palladium melts like lead ; every substance yields.

The student will find this indispensable, to ascertain their nature and habitudes ; and as they are often connected, the following notices of the many and varying appearances of the assay, alone or combined with fluxes, on supports of charcoal, metal, or glass, under the effect of the outer or inner flame, will direct his conclusions in reference to the results. When expense is disregarded, a series of ticketed mineralogical specimens are useful. He must also understand that the practical difference between the assay and the analysis of a mineral is—the assay determines the presence of a particular base, and the analysis demonstrates, from a definite weight, the

nature and precise quantities of all the valuable or worthless components.

The assay cannot be too thin, as only the point of the flame acts on it ; and olive-oil or water is used to form powders into a paste. The assay is tried on *supports* which do not chemically combine with it. Small pieces of *Alder charcoal*, four to six inches long, are useful for oxides and metallic minerals, as a perforation upwards will retain the whole assay, and also the oxygen which facilitates the process. Small slips of *platinum foil* enfold an assay, and unwrap after the process. Hooked *platinum wires*, two to three inches long, bear the flux to fuse into a globule, in which the assay is fixed by moisture, and all changes are very obvious. A small *glass matrass*, and an open *tube of glass*, three inches long, and one-eighth diameter, will receive an assay when volatile components not permanently gaseous are to be sublimed. A useful implement is a *pair of forceps*, with platinum points like ear-picks.

Roasting the assay in the glass tube, by heat, expels all the sulphur and arsenic ; known when Brazil wood test-paper does not bleach, neither is there an odour like that of garlic.

Decrepitation is prevented by first heating the charcoal and introducing the assay gradually from the upper end, bringing the flame on it till red-hot. Or, place the assay either in a groove between two slips of charcoal, or in melted borax, platinum tube or foil, matrass or tube, on which direct flame.

Reduction.—Metallic oxides, fused into a glass bead, the metallic particles form a globule ; soda is

added ; the heat is continued, and in the inner flame all is absorbed by the charcoal ; next cool by a drop of water. The assay is abstracted, ground fine in agate mortar, and by the dropping bottle carefully are washed away the soda and the charcoal.

The following *appearances* are constant : The assay, *alone*, either *does* or *does not* in the matrass evolve water—(to be tested)—change colour—decrepitate—give off volatile matter, odourant of garlic, (by arsenic), or brimstone (by sulphur), or horse-radish (by selenium), or by mercury. And *on charcoal*, in outer, then in inner flame, evolve volatile matter (as above), decrepitate—when roasted, be magnetic, melt—intumesce, or bubble—effervesce, or sputter—volatilise—colour the flame—burn—change colour—be absorbed by the support—fuse, and supply a bead, ash, globule, or enamel. And on charcoal, *with a flux*, fuse—intumesce—effervesce—change transparence—colour the flux—detonate—be absorbed—colour the flame—fuse, and yield a result as above.

A *Flux* added to the assay assists its fusion, and in the *dry way*, or with fire, has similar use to an acid, or an alkali, in the *humid way*. It acts chemically in separating the acid of a metallic oxide from the base, in also dissipating the oxygen and leaving the base pure. But mechanically when by it the compound agglomerates into a button.

The *three Fluxes* for mineralogical chemistry are thus prepared : The BORAX is common borax boiled a long time, evaporated, and in small crystals preserved, to be applied to *bits* of the assay (seldom to *powder*) by the moistened point of the knife.

SODA (indispensable to discover minute portions of reducible metals) is common subcarbonate in solution, and excess of nitric acid; by nitrate of barytes, separating sulphuric acid, and the muriatic, by nitrate of silver. The fluid evaporate, fuse, decompose with charcoal; wash the residue, crystallise the solution, and preserve the crystals. Or, dissolve subcarbonate in water, filter, slowly evaporate, skim off the small crystals, cool, crystallise, and preserve the crystals, to be used in fine powder, but in different proportions with silicious minerals, as a part may be absorbed by the charcoal support. MICROCOSMIC (or *Mic.*) SALT (Salt of phosphorus, or phosphate of soda and ammonia). Crystallise a solution of phosphates of soda and (excess) of ammonia (or 16 parts sal ammoniac and 100 phosphate of soda), heat, filter, and preserve the resulting crystals.

When the assay is opaque, decrepitates long violently, the globule is unchanged on platinum foil, but on charcoal expands, crackles, and is absorbed; or when on the platinum wire the bead fused by the inner flame gives a violet colour to the outer, the assay is POTASS. But when this is yellow, like that of a candle, SODA. And when at a red heat the platinum foil is corroded, a dull trace of yellow left, and the flame is a beautiful carmine-red, the assay is LITHIA (*red* with only potass; yellow with only soda). AMMONIA entirely volatilises. Also, put the red-hot fragments of alkaline minerals on test-paper, and round where they lie will be a blue stain.

When the assay alone, on charcoal or platinum, is not altered, but with borax effervesces and fuses

into a glass, clear but opaque, by flaming rendered milk white; also intumescing with mic. salt, and with soda absorbed; or a bit, held by platinum forceps at the point of inner flame, after some time gives a carmine-red colour to the outer, it is STRONTIAN; when the flame is not red, it is BARYTES. The globule, with solution of pure nitrate of cobalt, red-brown while hot, colourless when cold, indicates BARYTES; but black, not melted, STRONTIAN. This in chloride, on platinum wire at the point of the inner flame, causes the carmine colour, which ceases with fusion (thereby distinguished from chloride of *lithia*, which is constant).

When the assay alone, on charcoal or platinum, supplies an intensely brilliant light, yet is unaltered, and with borax forms a clear glass, opaque by flaming; or crystallise when the base is in excess, less milky than with barytes or strontia, with soda infusible, and with mic. salt easily fused into a transparent glass; or with solution of cobalt dark grey, infusible, the base is LIME. But when with soda no action ensues, with mic. salt the glass is clear but opaque, or milk white, and with solution of cobalt a flesh-red colour, cold by daylight, then it is MAGNESIA.

When the assay alone, on charcoal or platinum, is infusible, yet contracts, also, with borax effervescing much, slowly fuses into a transparent glass, not opaque by flaming or cooling; or with soda merely effervescing, expands, infusible; or with mic. salt violently effervescing, fuses into a clear glass, not opaque by saturation; or with solution of cobalt dried, and in inner flame long heated, becomes a fine

bright blue, cold by daylight, hot, or by other light a dirty violet, and which becomes only more beautiful in proportion to the quantity of cobalt, the base in ALUMINE.

When the assay alone, on charcoal or platinum, is infusible, but with borax slowly melts, uneffervescent, into clear glass not easily fused, nor opaque by flaming; or with soda (or charcoal) effervescing fuses into a clear glass; or with mic. salt and by long heat slowly and only partially dissolves, uneffervescing, a portion swimming in the flux a transparent inflated mass, the remainder semi-transparent, the glass permanently transparent; or with little cobalt pale blue, with much black (thus known from alumine), the base is SILICA.

When the assay alone, on charcoal or platinum, is splendidly brilliant, yet infusible, and with borax or mic. salt dissolves or fuses into a clear or transparent glass, milk white by flaming, or excess, not affected by soda, but with solution of cobalt becomes dark grey or black, the base is either GLUCINA, THORINA, YTTRIA, or ZIRCONIA (proved by tests, on a precipitate, by a solution of potass, not re-soluble in excess).

When the assay alone, on charcoal or platinum, is brown-red, infusible, but in inner flame with little borax fuses to glass, yellow-green, hot, colourless, cold, with much borax, when cold, crystalline enamel, white; in outer flame orange or beautiful red-hot, pale yellow, cold, or with mic. salt the glass a fine red-hot in outer flame, wholly disappearing in the inner, and colourless and clear, cold, or not affected by soda, which is absorbed, and there

remains (on the charcoal) a grey-white powder, the base is CERIUM.

When the assay, treated as in the preceding process, in the outer flame bubbles, gaseous, and forms a glass of clear amethystine colour, in inner flame without bubbling lost, yet in outer reappearing, or with soda, on charcoal, is not reduced, but on platinum foil fuses into glass, clear-green, hot, blue-green, cold, the base is MANGANESE.

When the assay alone, on charcoal or platinum, fuses, ignites in blue-green flame and white vapour, or with borax enlarges, then lessens, the flux spreads on the charcoal, or with mic. salt flashes, crackles, and detonates, or as oxide alone, on charcoal, yellow, then white, infusible, brilliantly ignited, and in inner flame white fumes, or with borax or mic. salt a clear glass, by flaming milky, or a white enamel, cold, or round the globule, in inner flame, on the charcoal white powder; similarly with soda reduced, or with solution of cobalt, a fine green glass, and with copper, the alloy *brass*, the base is ZINC.

When the assay alone, on charcoal, in outer flame oxidates black, and in inner reduces grey, infusible, or, a little with borax, or mic. salt, easily fuses into a transparent glass blue, or, with much black, yet red by transmitted light (the mic. salt violet), or, with soda, on platinum, fuses partially, red, hot, grey, cold; or, on charcoal, in inner flame, without fusing, forms a grey powder, the base is COBALT.

When the assay alone, on charcoal or platinum, is infusible (arseniate with soda only), but with a little borax fuses, becomes malleable and magnetic;

or, the oxide alone, in outer flame is black, in inner greenish-grey, or, with borax or mic. salt forms a dark-red glass, lost when cold, in inner flame black opaque, then grey and translucent, or with soda, on charcoal, readily reduces to a white metallic powder, the base is NICKEL.

When the assay alone, on charcoal or platinum, oxidates, infusible; or, with mic. salt solely, fuses; or, as oxide alone, on platinum fuses, but on charcoal, in outer flame is not altered, yet in inner becomes black and magnetic; or, with borax, or mic. salt, in outer flame forms a glass, dull blood-red, hot, or clear lighter yellow, cold; or, in inner flame is green, lost when cold, magnetic, or with much borax forms a green glass, or with soda is absorbed and reduced into a dark-brown metallic magnetic powder, the base is IRON.

But when the assay alone, on charcoal, forms an orange powder, or with borax, or mic. salt, on platinum wire fuses into glass, clear or yellow, hot, colourless or opaque, cold, and on charcoal bubbles, reduces, and sublimes into a yellow powder, the base is CADMIUM.

When the assay alone, on charcoal or platinum, easily fuses, irridisces, boils, fumes, or as oxides alone, on charcoal, in outer flame becomes black, yellow, and orange, in inner flame is reduced to a yellow coating, then to metallic globules, easily flattened by the hammer, or, with soda, reduced immediately, slightly colouring the flux, or, with borax, on platinum wire easily (mic. salt less easily) forms a glass, yellow, hot, colourless, cold, the base is LEAD.

When the assay alone does not sublime in the glass matrass, but on platinum easily fuses, or on charcoal in outer flame fumes, and a red mark remains, lost in inner flame (as are the greenish-blue of antimony and the deep green of tellurium); or as oxide alone on platinum in outer flame readily fuses to a brown glass, fine, cold, in inner reduces and perforates the support, or, on charcoal fuses into metallic globules, brittle and refractory, or, with borax in outer flame a grey speckled glass, in inner decrepitates, reduces, and volatilises, or, with mic. salt brownish-yellow, hot, pale, cold, the base is BISMUTH.

When the assay alone, on charcoal or platinum, by outer flame is not altered, but in inner fuses into a metallic globule, or with borax and mic. salt in outer flame fuses into a glass, fine green, hot, blue-green, cold, in inner dirty brownish-red, lost in charcoal, or with soda on platinum wire in outer flame melts into a glass, fine green, hot, colourless and opaque, cold, or in inner on charcoal is reduced, the base is COPPER.

When the assay alone, on charcoal or platinum, easily fuses without oxidation, or with soda in inner flame is reduced to a white globule, or with mic. salt in outer flame an opalescent glass, red by candle-light, yellow by daylight, or grey in inner flame; or as oxide alone is readily reduced, or with borax is partially dissolved, partially reduced in outer flame, a milky glass, grey in inner, or with mic. salt fuses opaque and whitish-yellow, cold, the base is SILVER.

When the assay, in glass tube, with dry soda,

iron filings, or oxide of lead, by a red heat reduces to a grey powder, or sublimes in the cold part, and by agitation is formed into globules, the base is MERCURY.

When the assay alone, on charcoal or platinum, is infusible, and not affected by any flux, yet by the cupel is reduced to a grey infusible porous metallic mass, the base is either RHODIUM, PALLADIUM, or IRIDIUM. (The first *soluble* in nitro-muriatic, the second in muriatic, the third in nitric acid.)

When the assay alone, gently heated, oxidates and volatilises with a pungent odour, like that of chlorine, the base is OSMIUM.

When the assay alone, or with any flux, on charcoal does not oxidate, yet fuses without colouring the flame, or in a cupel leaves a grey malleable metallic globule, the base is PLATINUM.

When the preceding effects occur at a red heat, the base is GOLD.

When the assay alone, on platinum or charcoal, readily melts, ignites, and oxidates, or, as oxide alone, on platinum in outer flame is yellow, then red, and in inner, ignited, is black, and with soda effervesces without fusing, or, on charcoal, with soda or potash, in inner flame white, reduced easily to a metallic lead readily flattened by the hammer, but with borax or mic. salt difficult to fuse, and forming a glass, or which renders a copper bead no longer green, but opaque and brown-red, the base is TIN.

When the assay alone, on charcoal, ignited, becomes dark brown, on platinum yellow without melting, or with borax or mic. salt easily forms glass white by flaming, in inner flame, dull

amethystine ; on charcoal dull yellow, hot, deep blue, cold ; or with soda effervesces, and forms a yellow glass, from outer flame, crystalline, and in cooling evolving much heat ; or with solution of cobalt, grey-black glass, the base is TITANIUM.

When the assay alone, on charcoal or platinum, easily fuses, and ignited burn with white dense fumes, which around the globule form beautiful pearl-like crystals, or, as oxide alone, on charcoal easily reduces, with a green flame, and on platinum easily melts, or with borax, on charcoal, forms a transparent glass, yellow, hot, lost, cold ; in inner flame grey, opaque, or with mic. salt, on platinum wire, in outer flame with borax, but with soda, in inner flame, reduces, and remains melted, and the white fumes are condensed reticular, the base is ANTIMONY.

When the assay alone, on charcoal or platinum, without smoke or fusion becomes yellow, brown, and black, or, with borax, on platinum wire, in outer flame (on charcoal in inner) fuses easily to a colourless glass, opaque by flaming, or with mic. salt in inner flame, a blue glass, more beautiful than with cobalt, lost in outer, recovered in inner, or with soda on platinum wire, yellow translucent glass, when cold crystalline, opaque, and yellow, or, on charcoal in inner flame reduces to a brilliant steel-grey metallic powder, the base is TUNGSTEN.

When the assay alone, on charcoal, is fused, absorbed, and reduced to grey powder, or on platinum melts in white fumes, in inner flame acidifies blue, in outer oxidates white, then brown, or with borax, on charcoal, in inner flame, fuses, and black

scales leave the glass clear, greenish, or, with mic. salt, in outer flame, a glass green, yellow, red, brown, and hyacinth, in succession, in inner, yellow-green, yellow-brown, brown-red, and black, or with soda, effervesces, a glass transparent, red, and paler, cold, the base is MOLYBDENUM.

When the assay alone, on charcoal or platinum, with a green flame remains unaltered, or with borax, in outer flame forms a glass, bright yellow, or yellow-red; in inner, greenish, even when cold, or with mic. salt in either flame, a glass emerald-green (but copper, green in only outer), or, with soda, on platinum wire, in outer flame, a glass orange, hot, yellow and opaque, cold; in inner, opaque green cold, absorbed, not reduced, the base is CHROMIUM.

When the assay alone, on charcoal, in outer and inner flame alternately, readily burns with a blue flame, and strong odour of garlic, or in glass tube with borax and charcoal powder, sublimes and deposits a crystalline or metallic result, the matter is ARSENIC (ACID).

When the assay alone, in a matrass, sublimes into a grey metallic powder, or, in open tube, a white, or on charcoal a green-edged blue flame, or on platinum melts and fumes, with the odour of putrid horse-radish, or, on charcoal, gently heated, becomes yellow, red, black, is fused, absorbed, and reduced, effervescing and detonating, or, with borax, or mic. salt, a glass on platinum wire clear, on charcoal grey and opaque, or with soda, on platinum wire, colourless, hot, white, cold; on charcoal, in inner flame reduced, the base is TELLURIUM.

When the assay, in an open tube, by outer

flame sublimes into a red powder, the base is SELENIUM.

When the assay, with soda and silica, on charcoal in inner flame render the glass bead dark brown, hot, red, cold, or with soda only, on charcoal, afterwards stains silver black or dark yellow, the matter is SULPHURIC (ACID).

When the assay, with borax, on charcoal, is fused and transfixed on harpsichord wire, then much heated in inner flame (forming carbonate and phosphate of iron), then the lead, cold, and in paper crushed, a grain of brittle magnetic metal appears, or the assay moistened with sulphuric acid, and by platinum forceps held in inner flame, thereby rendered green, the matter is PHOSPHORIC (ACID).

When the assay alone, on platinum, is not altered, but, with borax, a glass clear, transparent, opaque, or white-enamel, by flaming, or, with mic. salt, transparent, or, with soda, effervesces and combines, yet neither melts nor reduces, nor is blue with solution of cobalt, the base is COLUMBIUM.

When the assay alone, on charcoal, without fusing from yellow becomes black, or, with borax, in inner flame forms a greenish glass, with black specks, lost in outer flame, by yellowish-green or brown; then, in inner flame, green without specks; or, with mic. salt, or platinum wire, in outer flame, clear glass yellow hot, greenish-yellow cold; on charcoal, in inner flame, fine green, hot, more beautiful, cold, or with soda, yellow-brown, not dissolved, or reduced, the base is URANIUM.

When the assay, added to the dark-green bead, formed of mic. salt and oxide of copper, gives to the

whole flame a fine blue colour, or a greenish-blue, or a superb emerald-green, or a fine blue purple, the matter respectively is CHLORINE, BROMINE, IODINE, or MURIATIC ACID (rarely sought separately).

When the assay, with charcoal, fuses and detonates, or without fusing evolves orange vapour, the matter is NITRIC ACID.

When the assay, with 1 part of fluor spar and 4½ parts of bisulphate of potass, on platinum wire, at point of inner flame causes a green halo round the flame, the matter is BORACIC ACID.

When the assay, in open tube, with mic. salt (mica, etc., best in a matrass), heated a little corrodes the glass, and evolves a peculiar odour, the matter is FLUORINE, or FLUORIC ACID.

Attention to the appearances will preclude every possibility of error or mistake.*

* Assaying is also a method of ascertaining the quantity of gold or silver in an alloy. The baser metals are supposed valueless; and the problem is, simply, how much of the valuable component is present in the given quantity submitted to the assay. The assaying of gold or silver is divided into two operations; by one of which they are separated from the imperfect metals, or those easily oxidised; by the second they are separated from the metals which resist oxidation by simple exposure to the air, and which have, therefore, been called the *perfect metals*. This second process generally consists in separating gold and silver from each other, as the third perfect metal, platina, is seldom found united to them.

The method of separating gold or silver from the other metals is founded on the facility with which the latter imbibe oxygen, and the process is calculated to accelerate this operation; hence the oxide of lead, or litharge, is generally considered as the most powerful purifier of the perfect metals, from the ease with which it parts with its oxygen to the imperfect metals united with them.

But of late oxide of manganese has been found superior to it. In the chemical analysis of metals, the oxide of lead is generally preferred for the above purpose; but in the assays performed by order of government, metallic lead is always used, probably from the facilities which it is supposed to afford for determining the weight of different ingredients by calculation. The lead in the process first becomes oxidated, then yields some of its oxygen to the other imperfect metals, and afterwards becomes vitrified, in conjunction with the other oxides so formed, and carries them off with it, leaving the perfect metals pure and separate.

The above operation is called *cupellation,* and is performed on a flat round cake of bone-ashes, compressed within an iron ring, which is named a *cupel;* this is placed in a vessel called a *muffle,* which resembles a small oven, fixed in a furnace capable of giving a heat sufficient for the fusion of gold, so that its mouth may come in contact with the door, at the side to which it is luted, to separate it from the peal: there are small slits made in the sides of the muffle to afford a passage for the air.

As by this mode of operation we may certainly lose the elements of the substance examined, and only judge of the nature of the mineral, or other body, by certain appearances which take place during the immediate time of the operation, while propelling the flame of a lamp, when those substances which it is treating sublimes. To remedy this inconvenience in mineralogical research, and enable the operator to preserve all the elements of any solid substance examined in chemical analysis, when thus separated by this powerful agent, Mr. Gurney contrived a simple apparatus: a solid slab of plaster of Paris or of metal, with its upper surface ground perfectly true, that, a ground glass placed on it, remains air-tight on the edges, like as on the table of an air-pump. In the centre of the surface of this plate is a little furnace, into which terminates one of the jets belonging to the instrument, by perforating from the side through the solid part of the slab. Over the furnace fits a ground bell-glass, or part of a large tube, with a cap and stop-cock affixed, and the whole is completely air-tight. To the stop-cock is attached a bladder or silk bag in the usual manner.

To use this appendage in connection with the blow-pipe, place the substance to be examined into the little furnace; the jet which perforates the slab screw to the safety apparatus of the blow-pipe,

press the press-board, either by weight or the hand, the gas inflame at the jet by a taper, and the glass instantly invert over the furnace; the intense heat of the blow-pipe will fall on the mineral, and the whole of the volatile or gaseous parts will rise, and either be condensed on the inside of the glass, or in the gaseous form pass through the upper stop-tap into the bladder; thus all the elements will be retained, and may be examined by the proper tests after the action of the instrument has been discontinued. The glass remove, by placing the slab under water, either with or without the safety cylinder and flexible tube attached, without any possible loss of the contents, which may be decanted into smaller vessels for more accurate examination. Any solid substance, whether a mineral or chemical body, may be analysed in the same way, and the most satisfactory results obtained.

Should the water, formed by the combustion of the oxygen or hydrogen gases, be an objection to the immediate subject under analysis, a mixture of chlorine and hydrogen, in the proportions to form muriatic acid, may be used to produce the flame from the instrument.

HUMID ANALYSIS.

THE following General Course of Qualitative Analysis, perseveringly pursued through all its details, will be found of inestimable utility, because of the care with which each step of the several processes is particularised, and unremitted attention to accuracy in the elucidations. It is hoped no inconvenience can ensue from employing numerals to supersede many of the repetitions of the *names* of bases, etc., and of the re-agents which cause the most obvious phenomena in verifying them.

In each experiment, by employing only a small portion of the material, often will success ensue; while a large quantity will need more time, and might lead to error and disappointment.

The first manipulation, and the last when precision is expected, is, to *carefully estimate the quantity of the substance.*

A good balance, with grain weights, should be used; but when the weights used by apothecaries or silversmiths are employed, we reduce them to grains thus:—

Pound.	Ounces.	Drams.	Scruples.	Grains.
1	12	96	288	5760 Drugs
1	12	Pennyweights	240	5760 Troy

A sheet of best glazed post paper fold to the size of the scale; cut into pieces, and with scissors make the edges smooth, and adjust each piece to the same counterpoise; on this paper weigh the powder.

With mixed shot counterpoise the small crucibles. And a small glass jar, with a counterpoise, is used for great precision, as into it a fluid can be decanted, so as to add only drop after drop when near the equipoise.

All substances, whether *wholly, partially,* or *not in any degree solicited to separation* by pure water, or dilute muriatic, or nitric acid, are formed of component elements, which are classed as BASES, ACIDS, and NON-METALLIC BODIES.

(A) BASES.

1. Potash.
2. Soda.
3. Lithia.
4. Ammonia.
5. Barytes.
6. Strontia.
7. Lime.
8. Magnesia.
9. Alumine.
10. Glucina.
11. Thorina.
12. Yttria.
13. Cerium.
14. Zirconia.
15. Protoxide of Manganese.
16. Oxide of Zinc.
17. Oxide of Cobalt.
18. Oxide of Nickel.
19. Protoxide of Iron.
20. Peroxide of Iron.
21. Oxide of Cadmium.
22. Protoxide of Lead.
23. Oxide of Bismuth
24. Deutoxide of Copper.
25. Oxide of Silver.
26. Protoxide of Mercury.
27. Peroxide of Mercury.
28. Oxide of Gold.
29. Protoxide of Tin.
30. Peroxide of Tin.
31. Protoxide of Antimony.
32. Oxide of Platinum.
33. Oxide of Chromium.

(B) ACIDS.

1. Sulphuric *a.*
   Sulphurous *b.*
2. Nitric *a.*
   Nitrous *b.*
3. Chloric.
4. Bromic.
5. Iodic.
6. Phosphoric.
7. Boracic.
8. Carbonic.
9. Silicic.
10. Chromic.
11. Arsenic *a.*
    Arsenious *b.*

(C) NON-METALLIC BODIES.

12. Chlorine. 14. Bromine. 16. Sulphur.
13. Fluorine. 15. Iodine.

Combined with the Metal of a Base.

When any of these are obtained by a process, it is verified by several of the following re-agents soliciting it, and supplying distinctive characteristic colours by their *Solutions*:—

1. Caustic Potash.
2. Caustic Ammonia.
3. Carbonate of Potash.
4. Bicarbonate of Potash.
5. Carbonate of Ammonia.
6. Phosphate of Soda.
7. Oxalic Acid.
8. Binoxalate of Potash.
9. Ferrocyanate of Potash.
10. Red ditto of Potash.
11. Chromate of Potash.
12. Iodide of Potassium.
13. Hydrosulphuret of Ammonia.
14. Sulphuretted Hydrogen Gas.
15. Do. do. Water.
16. Succinate of Ammonia.
17. Protosulphate of Iron.
18. Protochloride of Tin.
19. Cyanuret of Mercury.
20. Protonitrate of Mercury.
21. Tartaric Acid.
22. Carbazotic Acid.
23. Hydrofluosilicic Acid.
24. Sulphuric Diluted Acid.
25. Diluted Nitric Acid.
26. Diluted Muriatic Acid.
27. Chlorides.
28. Sulphate of Potash.
29. Muriate of Platinum.
30. Muriate of Barytes.
31. Alcohol.
32. Nitrate of Silver.
33. Nitrate of Cobalt.
34. Muriate of Ammonia.
35. Acetate of Lead.
36. Nitrate of Barytes.
37. Acetate of Barytes.
38. Muriate of Gold.
39. Metallic Zinc bar.
40. Metallic Copper bar.

PREPARATORY MANIPULATIONS.

THE following manipulations depend only partially on the skill or dexterity of the operator, and hence are very useful.

(*a*) When the powder to be used in the analysis is a neutral compound, without the presence of free acid or alkali, make the porcelain mortar warm, and into it put twenty grains of pure hydrate of potash (or of soda, when magnesia is absent), with five grains of the powdered mineral, quickly triturate them with a glass rod, and with a dry feather carefully clean the whole out into a crucible, and moisten with pure water.

(*b*) The mixture put into a silver crucible, and cover closely (or into one of platinum with a cover, which place within a cylindric one of porcelain, also to be closely covered), place in the Lamp furnace,* and gradually raise the temperature to incandescence, in which state keep it not less than *eighty minutes* (else a repetition may be needed) to fuse the mass into a paste. This, when cool, will be glass, when the chief component is silica, or imperfectly vitrified, with enlarged bulk, when it is alumine; with the

* The Lamp furnace of Lowitz will burn either spirit, pyroacetic acid, or best olive oil. It has two concentric wicks, the outer, two inches, the inner, one inch, in diameter; a copper chimney, four inches high, and three in diameter, having air-holes; also a cover adapted to receive a fine silver crucible, that will contain three ounces. (Messrs. Jones, Holborn, supplied that I use, and with its power I am well satisfied.)

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presence of iron indicated by a brown tint; or manganese by a bright grass-green, affecting water; or chromium, by a greenish-yellow.

Another lamp furnace is thus described and figured by Mr. Griffin, in a Note in his edition of Rose's *Manual*, page 49: "The spirit-lamp, with circular wick, or double current of air, is one of the most indispensable articles of apparatus of the analyst; for many accurate experiments cannot be performed without it. The wick passes between two cylinders, which are connected below by a horizontal plate, and are raised or depressed by means of the toothed wheel *e* and the toothed bar *g*. The lower end of the latter is connected with a cross bar, upon the end of which is fastened a ring whereon the wick is stuck. The cross bar works up and down in the box *b*. This box does not form part of the spirit-holder *a*, as it does in the common lamps, but is separated from it by the open spaces *t t*. The spirit passes from *a* into *b* by a small pipe, which passes diagonally from the under part of *a* nearly to the bottom of *b*, something in this manner *V*. The object of this contrivance is to prevent the explosion which frequently takes place when the common spirit-lamps are inflamed, and which is owing to the mixture of atmospheric air and vapour of alcohol which exists in the spirit-holder *a*. At *m* is an opening by which the spirit is poured into the lamp. This is afterwards closed by a cork. In the front of the lamp, at *s*, a piece of glass is cemented, to afford an opportunity of readily ascertaining how much spirit the spirit-holder *a* contains. The lamp is provided with a copper chimney. The wick must be cut quite level, and must never remain in a charred state. The figure represents a lamp of this sort, drawn according to a scale of one inch and three-quarters to a foot. With a lamp such as this, 380 grains of

(*c*) Into a porcelain capsule shake the contents before they are cold by gently pressing the sides of the crucible; fill the crucible with pure water, boil this two minutes, and repeat this till the inside of the crucible is completely washed from the most minute particle of the fused mass, adding each liquid into the capsule. Into a test-tube of this solution drop muriatic acid, and if the tint be orange-red, iron is present; a purplish-red, manganese; and a golden-yellow, chromium. Sometimes muriatic acid is employed at first to wash out the crucible, but not only may loss ensue by the effervescence, but when manganese, cerium, or chromium is present, chlorine will evolve, and corrode the platinum crucible. Indeed, platinum vessels must not be used in any process whenever there is present oxide of lead, or of copper with charcoal, or peroxide of lead or manganese with muriatic acid, or chlorine, or regulus of metals.

carbonate of soda may be fused in about fifteen minutes, the salt being placed in a platinum crucible of the weight of from 300 to 380 grains, and large enough to contain an equal weight of water. A lamp which is incapable of effecting the fusion of at least 180 grains of carbonate of soda is unfit for use. The experimental chemist should possess two lamps of this description, one for fusing and another for other experiments. In the latter case the rods which support the lamp may be strong, but for the other lamp the rods may be as thin as possible, in order that they may not carry away too much of the heat." No doubt Messrs. Jones will supply this lamp, perfectly constructed, on as moderate terms as any other philosophical instrument maker. Having had dealings with them during twenty years, to a considerable amount, I can with more confidence give an opinion.

The fact is very remarkable, that by much the greater number of the elements mentioned in page 27 are the productions of the laboratory, and never presented pure by nature. The discoveries and knowledge of other persons makes the student acquainted therewith ; and he desires to know how he can most readily render tangible and obvious the BASES, whose combinations form all subjects of existence, the globe and its numerous and beautiful embellishments. In the contemplation of these subjects—on such as cannot be brought to the test of experiment—the fancy is at full liberty to enjoy itself, to hazard conjectures and supply expositions ; but like procedure must never be attempted with the others of a contrary character, because every person acquainted with the subject could prove the conjectures erroneous, and the explanations absurd.

The subsequent general and particular analytic processes carefully detail the best established and most general methods by which the student can perform, with the greatest probability of success, the numerous nice and delicate experiments which are adapted to supply intimate acquaintance with the relations of substances to each other reciprocally, their mutual dependence, and connection as a whole ; and also the laws by which all the phenomena are governed and can be explained.

The combinative potency of pure water, muriatic and nitric acids, concentrated or diluted, will suggest the most successful processes for separating substances, whether binary or mixed compounds, into their respective component elements. They, therefore, shall be elucidated agreeably to their characters.

CLASS I. Many substances, binary compounds, whose component elements are only a base and an acid—a metal and a now metallic body (as chlorine in chlorides, fluorine in fluorides, cromine in cromides, iodine in iodides, and sulphur in sulphurets)—are completely separable into those elements by a sufficient quantity of pure water.

CLASS II. Many such binary compounds, by pure water only partially separable, are completely so by muriatic or nitric acid.

CLASS III. Many binary compounds are wholly inseparable by pure water, muriatic, or nitric acid, as chloride of 25, protochloride and sulphuret of 26, and sulphurets of 5, 6 7, 22; also many acid, phosphates, and some acid arseniates, after long incandescence.

CLASS IV. Many mixed compounds of two or more bodies are completely separable by pure water.

CLASS V. Many such mixed compounds, only partially separable by pure water, are completely so by muriatic or nitric acid.

CLASS VI. Many mixed compounds are only partially separable by pure water, muriatic, or nitric acid, and the residue are substances separable by only certain processes.—(*See* III. above.)

GENERAL ANALYTIC PROCESSES.

Class I.—*Compounds soluble in Water.*

TO FIND THE BASE.

1. The compound treat with pure water till it is completely separated; afterwards concentrate by evaporation till there is the commencement of a pellicle on the surface. To a small portion of this liquid in a test-tube drop muriatic acid, and if a *white* precipitate fall, *nitric* must be substituted for *muriatic* acid in the next manipulation.

2. The solution slightly acidulate (to redden litmus test-paper), to completely saturate and prepare the solvent for tests.

A. 3. Add test 15 till the liquid gives out the odour. Where there is *no* precipitate the base is in 1 to 19 inclusive, but it is in 20 to 33 when there is one. When this is black, the base is in 22 to 28, thus determined :—

(1.) Into several test-tubes pour a little of the liquid, and whenever the first directed test is inefficient, proceed to the next, and so in succession, with each of the others, until some definite characteristic appears.

[a] Into one tube drop test 2; a deep-blue tint, without precipitate, not changed by excess of the test, shows the base 24, Deutoxide of Copper. To verify this, redissolve the precipitate in muriatic acid, and the diluted solution will supply precipitates of the specified colours: 1, 3, blue; 2, green;

4, 5, 6, 7, greenish; 9, 11, red-brown; 10, yellow-green; 13, 14, 15, black; 12, white; 36, black coating; 38, orange-red.

[b] To the liquid add much water, and a milky fluid shows the base 23, OXIDE OF BISMUTH; which, as above directed, verify: 1, 2, 3, 4, 5, 6, 9, white; 7, crystalline; 10, yellowish; 11, yellow; 12, brown; 13, dark brown; 14, 15, black; 36, black spongy mass.

[c] Into the liquid drop test 26, and a white precipitate, insoluble by dilution, shows base 25 or 26; thus discriminated: Into the liquid (1) drop test 2; a precipitate black, and weaker by excess of test, or, in the aciduline liquid, an insoluble grey precipitate, shows the base 26, PROTOXIDE OF MERCURY; thus verified—1, 2, 4, 5, 13, 14, 15, black; 3, dirty yellow; 6, 7, 9, 26, 27, white; 10, red-brown; 11, red; 12, greenish-yellow. But no precipitate in the aciduline liquid by test 2, yet by it in dilute liquid, a brown one, soluble in excess, shows the base 25, OXIDE OF SILVER; thus verified—1, 2, brown; 3, 4, 5, 7, 9, 12, 17, 18, 26, 27, white; 6, yellow; 10, 11, red-brown; 13, 14, 15, black; 36, black beneath white.

[d] To the liquid add test 1; a yellow precipitate shows base 27, PEROXIDE OF MERCURY; thus verified—10, yellow; 2, 5, 6, 7, 9, white; 3, 4, red-brown; 11, yellowish-red; 12, cinnabar-red; 13, 14, 15, black.

Into the liquid drop test 17; a brown metallic precipitate shows base 28, OXIDE OF GOLD; thus verified—1, 14, 15, 20, black; 2, 5, yellow; 7, greenish-black; 9, emerald-green; 12, yellowish-

green; 13, dark brown; 17, first blue, then brown; 18, red purple.

f Into the liquid drop test 24 or 25; a white precipitate shows base 22, PROTOXIDE OF LEAD; thus verified—1, 2, 3, 4, 5, 6, 7, 9, 24, 25, 26, 27, white; 11, 12, yellow; 13, 14, 15, black; 36, blackish-grey spangles.

(2.) When the precipitate, 3, is milk white, the base is 20, PEROXIDE OF IRON; thus verified—1, 2, 3, 4, 5, red-brown; 6, white; 9, blue; 13, black.

(3.) A yellow precipitate, 3, shows the base 30 or 21, thus discriminated: by ammonia neutralise the aciduline liquid;

g To the liquid add test 13; a yellow precipitate, insoluble in excess of the test, shows the base 21, OXIDE OF CADMIUM; thus verified—1, 2, 3, 4, 5, 6, 7, 9, white; 10, 13, 14, 15, yellowish; 36, grey spangles. But a soluble precipitate shows base 30, PEROXIDE OF TIN, thus verified—1, 2, 3, 4, 5, 6, white; 13, yellow.

(4.) A dark brown precipitate, 3, shows the base 29, PROTOXIDE OF TIN; thus verified—1, 2, 3, 4, 5, 6, 7, 9, 10, white; 11, white flocculent; 13, brown.

(5.) An orange-red precipitate, 3, shows the base 31, PROTOXIDE OF ANTIMONY; thus verified—1, 2, 3, 4, 5, 6, 7, 9, white; 13, red.

B. 4. When the solution, 2, is indifferent to the solicitings of sulphuretted hydrogen (test 15), neutralise by ammonia (test 2); then add hydrosulphuret of ammonia (test 13), and when there is no precipitate the base is in 1 to 8, but in 9 to 19 when there is one. When this is black, the base is in 17 to 19, thus determined:—

(1.) Into the liquid drop test 3; a precipitate—

[a] In succession white, green, and brown-red at the surface, shows the base 19, PROTOXIDE OF IRON; thus verified—1, 2, 3, 4, 5, 6, white; 7, 8, yellow; 9, 10, blue. Dirty red shows the base 17, OXIDE OF COBALT; thus verified—1, 2, 6, blue; 3, 4, 5, red; 9, green; 10, red brown. Bright green shows the base 18; OXIDE OF NICKEL; thus verified—1, 3, 4, 5, 7, 10, green; 6, 9, white.

(2.) A flesh red precipitate, 4, shows the base 15, PROTOXIDE OF MANGANESE; thus verified—1, 2, 3, 4, 5, 6, white; 7, white crystalline; 9, white or pale red; 10, brown.

(3.) A white precipitate, 4, shows the base 16 or 9, thus discriminated: [b] Into the liquid drop test 2; a white precipitate, in excess of test soluble, shows the base 16, OXIDE OF ZINC; thus verified—1, 2, 3, 4, 5, 6, 7, 9, 14, 15, white; 10 yellowish-red. But one insoluble, shows the base 9, ALUMINE; thus verified—1, bulky; 2, 3, 4, 5, 6, very voluminous. An insoluble one, which dissolves by test 5, shows the base 10, GLUCINA; thus verified—1, 2, 3, 4, 6, copious; 13, slight.

C. 5. When neither tests 15 nor 13 solicit a precipitate in the aciduline solution, 2, to the neutral solution, 4, add test 3; a white precipitate shows the base in 5 to 8.

(1.) [a] Into the liquid drop test 2; a white flocculent precipitate shows the base 8, MAGNESIA (not appearing in an aciduline liquid); thus verified—1, 3, voluminous; 2, bulky; 6, very slight.

(2.) The liquid put into a lead capsule, and drop into it test 23, and leave 8 days to repose. A preci-

pitate shows the base 5, BARYTES; thus verified—1, voluminous; 3, 4, 5, 6, 24, white, copious; 16, very quick. But no precipitate shows the base 7 or 6, thus discriminated:[b] The solution, 5 or 2, dilute much; add test 28 or 24; an immediate precipitate shows the base 6, STRONTIA; thus verified—1, 4, 5, 6, 24, white; 7, 8, troubled. But sluggishly a crystalline precipitate shows the base 7, LIME; thus verified—1, 3, 4, 5, 6, 7, 8, white.

D. 6. When the aciduline solution, 2, is indifferent to the tests 15, 13, and 3, the base is in 1 to 4.[a] Over it, near, hold a glass rod, moistened with test 26, and white vapours—or, on dropping into it test 1, the odour of ammonia—shows the base 4, AMMONIA; thus verified—21, crystalline, 23, copious; 29, bright yellow.

[b] When the two last fail, add test 29; a yellow precipitate shows the base 1, POTASH; thus verified—21, white crystalline; 22, bright yellow crystalline; 23, transparent, gelatinous. When there is no precipitate the base is 2, SODA; by 23, opalescent.

The aciduline solution, 2, neutralise by ammonia; add test 6; a copious, sluggish precipitate shows the base 3, LITHIA; thus verified—28, copious; 29, little troubled; 4, very sluggish, but fine.

TO FIND THE ACID OR THE NON-METALLIC SUBSTANCE.

E. 7. When in the first solution, 2, test 26 causes effervescence, either acid 8 or sulphur combined with a metal of one of the bases is present. When the evolving gas is inodourous, it proves the presence of acid 8, Carbonic; but when odourous the solution contains a sulphuret.

F. 8. When test 26 does not cause effervescence, neutralise the solution, and by evaporation concentrate. Add test 29; a *white* precipitate shows the acid is 1, or 6, or 11, or 7; or that 13 is combined with a metal of one of the bases, thus determined:—

(1.)[a] The precipitate treat with test 26, and no change ensues when acid 1 is present, Sulphuric; thus verified—30, 3 (boiled in), solicits, and forms an insoluble compound.

(2.) When separation of the precipitate ensues, 6, 11, 7, or 13, combined with a metal of one of the bases, is present. [b] In a leaden capsule put a little of the powder, 1; add test 24, cover with glass-plate, previously warmed, and well-coated with bees'-wax, through which distinctly are traced to the glass whatever lines may be thought proper; raise the temperature a little, again reduce it, examine the glass, and when its surface is corroded in the tracings, the compound is a *fluoride*, and as such must be analysed.

[c] When the glass is not corroded, moisten with test 24, next add test 31, inflame, and a green blaze shows acid 7, Boracic; thus verified—to the solution 1, add test 20, 32, white precipitate, 30 soluble.

Moisten with test 26, next add test 15, and boil; a yellow precipitate shows acid 11, ARSENIC; thus verified—32, brown; but when there is no precipitate, acid 6, PHOSPHORIC, is present; thus verified—30, 35, white; 32, yellow.

(3.) To the solution add test 32; a white flocculent precipitate, insoluble in dilute nitric acid, shows a *chloride* of the metal of one of the bases; thus verified—24, muriatic acid gas evolves.

(4.) Strew the powder on red coals; increased combustion with deflagration show acid 2, NITRIC; thus verified—17, crystals; 24, dark brown.

(5.) To the solution add test 26; a red-brown tint shows acid 5, IODIC; thus verified—14, 24, greenish-yellow vapours; or 24 (heated), violet vapours.

(6.) To the solution add test 20; a yellowish precipitate shows acid 4, BROMIC; thus verified—32, white; 24, hyacinth-red vapours.

Class II.—*Compounds soluble only in Acids.*

TO FIND THE BASE OR THE METAL.

1. When the powder contains a sulphuret, or base 22, or 25, or 26, form the solution with nitric acid, raising the temperature; but other solutions form with muriatic acid, and raised temperature when required.

2. In several test-tubes put a small portion of the solution, and dilute. Add test 15; a precipitate shows the base in 20 to 33; which determine, and verify as already directed, Class I., A. 3.

A. (1.) When acid 11 is present, keep its sulphuret in the acid at 120° several days, the test 14 strongly soliciting the precipitate; this must be filtered out as quickly as possible; boil the liquid, the precipitate try by blow-pipe for metallic arsenic. Metallic oxides are quickly precipitated with characteristic colours.

B. (2.) When test 15 fails, alkalinise by test 2; then add test 13; a precipitate becoming black shows the base 17 to 19; thus determined (and in every instance to be verified as before directed): " On platinum foil, with a flux and blow-pipe, fuse the powder; the assay blue, shows the base 17; red, 18; deep red, 19. To the acid solution add test 9; green, 17; white, 18; blue shows the base 19.

(3.) A flesh-red precipitate (2.), or one which becomes so, shows base 15.

(4.) A white changeless precipitate shows the

base 16 or 9 (except acid 6 or 7 is combined with bases 8 to 5, or these combined with 13); thus discriminated :—

[b] The powder mix with soda, or moisten with test 33, and on charcoal subject to the inner blow-pipe flame; which white changing into green, shows the base 16. Also, when test 2 causes a precipitate, soluble in excess; or this by test 13 is insoluble in tests 1 and 2.

[c] The powder moisten with test 33, and subject to the inner blow-pipe flame; a blue assay shows the base 9; also, when the precipitate (2.) is and continues soluble in test 1.

[d] The acid solution, dilute; add test 24; a white precipitate; or add test 23, and leave twenty-four hours to repose; a precipitate in both instances shows base 5; but no precipitate by either process shows base 6. Or, add test 31; a white precipitate shows base 7; but no precipitate, the base is 8; also when the powder, moistened with test 33, on charcoal subjected to inner blow-pipe flame, gives a pale red assay.

C. 5. When tests 15 and 13 fail to cause a precipitate, to solution [d] add excess of test 3; a precipitate, either sluggish or by long boiling, shows the base in 8 to 5; thus determined :—

[a] To dilute solution add tests 24 or 28; a precipitate shows base 6; or 5 when test 23 renders it white after many hours repose. But when there is no precipitate by these alkalinise by test 2, then add test 34; also, add test 8; a white precipitate shows base 7. Or, when 34 and 8 fail, add test 6, a white precipitate shows base 8.

TO FIND THE ACID OR NON-METALLIC BODY.

D. 6. The powder moisten with muriatic acid; gently heat; and effervescence and gas, without odour, prove the acid 8; but sulphur and a metal when offensively odourous.

[a] When there is excess of base, by F. 8 (4.), seek the presence of acid 2.

[b] The powder mix with soda, fuse on platinum foil in blow-pipe inner flame; a garlic odour proves acid 11. Processes F. 2. [b c] will detect a fluoride and a borate. [d] In cold nitric acid dissolve the powder; dilute, add test 32; a white precipitate shows a chloride. [e] Heat this solution; reaction ensues during the evolving of nitrous acid vapour, with deposit of sulphur by long digestion; dilute; add test 36; a white insoluble precipitate proves a sulphuret present. When this is of base 26, 29, or 31 (but not of base 22), the solvent must be nitro-muriatic acid, and chlorine gas will evolve, the result being respectively the sulphate, the peroxide, and the protoxide. [f] When the substance has excess of base, to the dilute muriatic solution add test 30 (to the nitric, test 36); a white insoluble precipitate proves acid 1; which verify, as before directed. [g] The powder mix with protoxide of lead, base 22; and on charcoal, fuse by blow-pipe flame; the assay crystallising while cooling shows acid 6. Likewise verify; with test 30 and 36 white, 32 yellow.

Class III.—*Compounds not soluble in Water or Acids.*

TO FIND THE BASE.

1. The powder mix with soda, or moisten with test 24; on charcoal, the blow-pipe flame green, proves acid 6. Phosphates and arseniates boil in concentrated sulphuric acid, and add pure water; only when the base is 5, 6, 7, or 22, these all being, though unequally, insoluble in water.

2. [a] The powder throw into nitro-muriatic acid; the deposit is 16, SULPHUR; add test 30; an insoluble precipitate shows sulphuret of base 26; with test 1 a yellow precipitate shows it of 27. [b] Mix the powder with soda; in a test-tube heat, and metallic mercury appears; heat the powder alone, and the assay will be red, whether the base be 26 or 27.

3. The powder moisten with test 13; the white changing to black proves the base 22 or 25; with acid 3; thus discriminated—In glass tube over the lamp heat the powder; sublimation proves protochloride of 22; fusion, chloride of 25; indifference, sulphate of 22.

4. In water digest the powder; to a portion of the liquid add test 30, to another, test 8; white precipitates; the former, insoluble in acids, prove sulphate of base 7.

5. The powder digest in test 3; filter, acidulate with test 26; add test 30; an insoluble precipitate proves a sulphate of base 5 or 6; thus discriminated—the aciduline liquid filter, concentrate, add test 31, inflame; a red flame shows sulphate of base 6, and of 5 when not red; or, in leaden capsule add test 23; no precipitate proves base 6; as base 5 is showed by one white and extremely sluggish.

Class IV.—*Mixed Compounds soluble in Water.*

TO FIND THE BASES.

Proceed as directed (1, 2, Class I.) to acidulate the watery solution.

A. 1. Add test 15, and warm the liquid; a precipitate proves the bases in 21 to 33 (or 20 when white and milky, or with acid 11, when yellow, soluble in test 13). When precipitation ceases, carefully decant, and preserve the liquid for testing.

(1.) The precipitate moisten with test 2, then add test 13; entire disappearance proves the bases in 28 to 31, thus determined: [a] The diluted solution acidulate with test 26; the precipitated sulphurets, peculiar in tint (paler because of the sulphur present), thus discriminate: [b] To the dilute liquid add test 18 (or 17), a red-purple (or a brown) metallic precipitate proves the base 28. [c] To the dilute liquid add tests 9, 10, or 11; a white, flocculent precipitate shows the base 29. The very dilute liquid, milky, or supplying a red precipitate, proves the base 31, or 30 when yellow. Or, [d] the precipitate (1.) mix with soda, and, on platinum foil, fuse in the blow-pipe inner flame—a smoke off the assay, and then reticular crystals, show the base 31, not 30.

(2.) Indifference to tests 2 and 13 shows the base in 21 to 27. [a] Dilute the solution much, filter out, and preserve whatever is insoluble, then acidulate with test 26; a milkiness shows test 13 entirely inefficient to separate anything, as does complete

evaporation. [b] The precipitate on filter wash well; digest filter and contents in concentrated nitric acid, and the sulphur (yellow precipitate) filter out. The strong acid separates the sulphuret of mercury. Mix the powder with soda, and in a test-tube, by blow-pipe heat, sublime; no change proves the base 27; change to a grey powder, by trituration rendered metallic, shows the base 26. [c] The sulphur ([b]) may have present sulphate of lead when the base 22 was in combination, though most of it would be separated by the nitric digestion. [d] The acid solution alkalinise with test 2; a blue tint shows the base 24. [e] Add test 26; a white precipitate, disappearing in test 2, shows the base 25. [f] The diluted solution treat with test 24; a white precipitate shows the base 26. [g] Much of the acid dissipate by evaporation, add pure water in excess; a milky liquid proves the base 23. [h] The powder mix with soda, and on charcoal, in blow-pipe inner flame, a brownish-red (not yellow) assay proves the base 21.

B. (2.) On platinum foil evaporate two drops of the liquid A. 1.; complete evaporation proves the absence; but a residue, one or more in 19 to 9, of fixed bases.

(1.) [a] The liquid alkalinise with test 2; add test 13; the precipitate filter out, and wash well with water, odourated with test 13. [b] The precipitate and filter digest in test 26 till inodourous of test 14. When base 18 or 17 is present, add test 25; filter, and the precipitate digest in nitric acid; add test 2, the precipitate filter, wash well; white shows the base 9, brown 9 and 20; thus discriminated: [c] In test 26 dissolve the filter and its contents; filter;

to liquid add test 1; a precipitate proves the base 20; indifference proves it 9, as will a white precipitate on adding test 34. [d] The test 3 will give a white or a red-brown tint to the precipitate, as the base is 19 or 20.

(2.) The liquid (1 [a]) with a blue tint, proves the base 18; rose-red, or a blue assay in blow-pipe flame, the base 17. [a] To the solution add test 1; a precipitate bright apple-green shows the base 18, but brown by the atmosphere the base 15; also this discriminated by the blow-pipe flame when mixed with soda and fused on charcoal, a white metallic magnetic assay, 18; on platinum foil, the assay, amethystine or green, 15. [b] To the liquid last left add test 13; the precipitate roast on charcoal by the blow-pipe; the assay, amethystine or green, proves the base 15; white powder, 16, also green, with test 32; and 17 grey magnetic powder.

C. On platinum foil evaporate two drops of the solution B. 2, and cease when all disappears; but a residue may have the fixed bases 8 to 1 (except 4).

(1.) [a] Acidulate with test 26; by heat dissipate test 14; filter out the sulphur; alkalinise by test 3; by heat dissipate acid 8; a precipitate is in 7 to 5. [b] The precipitate dissolve in test 26; add test 28 or 24; an immediate precipitate may be of all three; a sluggish one only 7; thus determined: [c] The dilute alkaline liquid acidulate with test 24; warm; filter; then alkalinise the liquid with test 2, and add test 7 or 8, for base 7, with twenty-four hours repose. When 7 appears the precipitate with test 24 also contains it; but otherwise this precipitate contains both of either of 6 and 5; thus discriminated: [d] In

a leaden capsule to the solution ([a]) add test 23; a very sluggish precipitate is base 5; but 6 when there is none. [e] The precipitate ([c]) heat long on charcoal in blow-pipe inner flame; then dissolve in test 26, and evaporate dry on platinum foil; the residual salt place on a wedge-shaped strip of paper, moisten with test 31, alcohol, inflame; red proves base 6 present (or with 5 also); absent when not red; find 5 by process [d].

(2.) The liquid after (1 [a]) on platinum foil evaporate; when all flies off, cease; when there is a residue: [a] To the liquid add test 6; a white precipitate proves 8 present. When there is no precipitate: [b] In a porcelain capsule evaporate dry, and, by heat, dissipate all salts with test 2; in diluted test 31 mix or separate the powder; add test 29; a bright yellow precipitate proves base 1; when there is no precipitate base 2 may be present, as also with the other; thus determined: [c] A little of the powder [b] on platinum wire in blow-pipe inner flame, is blue for base 1, yellow for 2, or 1 and 2 together. For 3 proceed as before (1. D. 6.[c]).

[d] The liquid (2 [a]) evaporate, the residue ignite; acidulate with test 37; the precipitate filter out, and verify by the blow-pipe. [e] The liquid (with excess of acetates of bases 5, 8, 1, and 2, present) evaporate dry, and the residue ignite, and dissolve in water; the latter two when present do not precipitate as do the former two. [f] By heat dissipate acid 8, and the base 8 remains, caustic but insoluble. To the alkalies add test 26, and the resulting chlorides discriminate as before. [g] Heat the powder (A. 1.) in test 1; hold over it a rod moistened with test 26, to prove base 4.

TO FIND THE ACIDS, ETC.

A. 1. [a] To a portion of the concentrated solution (A. 1) add test 26; effervescence and inodourous gas prove acid 8 present and 16 absent; but odourous prove a sulphuret of a metal, and 8 may also be present. [b] To another portion (not acid) add test 30 (when bases 22, 25, 26 are absent, otherwise test 36); a precipitate proves there may be present 13, 6, 7, 11 (and 8 when test 30 is used). [c] When proper employ diluted nitric acid, else add test 26; the resulting precipitate is soluble when acid 1 is absent. The precipitate dissolves, effervesces, and remains soluble when the liquid is aciduline, boiled, and alkalinised by test 2, for acid 8 alone. When test 2 troubles the liquid, 8 may be present with one of the other acids. The absence of phenomena intimates there is one, if not all of 6, 7, 11, and 8.

(2.) [a] In a leaden capsule put some of the powder; add test 24, and cover with waxed traced glass; corrosion proves 13. [b] Add tests 24 and 31, inflame, a green tint proves acid 7. [c] To the solution (1 [a]) add test 15; a precipitate proves acid 11 (present only with alkalies when soluble, and only soluble when in excess combined with earths and metallic oxides; hence no oxide will discolour its precipitates). [d] To the solution add test 30; a precipitate, soluble in tests 26 or 25, but again appearing when treated with test 2, proves acid 6.

(3.) [a] The solution alkalinise with test 15, boil, filter out the sulphuret of acid 11; neutralise with

test 2; add test 30; a precipitate, insoluble in pure water, proves acid 6, or 7 if soluble. (4.) To the powder, in a platinum capsule, add test 24; by heat dissipate all vapour; the residue mix in water, acidulate with test 26; add test 30; filter out the precipitate (sulphate of base 5); add test 2; a precipitate proves acid 6 present. (5.) When the precipitate (4) is not completely soluble in tests 26 or 25, the acid 1 is present; and the liquid after filtering treat as just directed for 4, 6, 7, 11. (6.) To solution add test 32; a white solution, insoluble in test 25, proves a chloride present. (7.) Throw powder on glowing coals; deflagration proves acid 2 present.

Class V.—*Mixed Compounds soluble in Acids.*

TO FIND THE BASES.

A. 1. The powder mix well in pure water; filter, and the watery solution treat as already directed in Class IV.

2. The filtered portion dissolve in the proper acid. [a] This solution alkalinise with test 15; filter out the precipitate. [b] To the liquid add test 13; a precipitate proves bases 30 or 31, or acid 11. (Verify each result as before.) To discriminate these: [c] By the blow-pipe flame and odour prove acid 11. [d] The precipitate moisten with water; add test 26, and solution will ensue when base 31 is present with sulphur. [e] The liquid ([b]) dilute; add test 26; the precipitate filter out, dry, and in closed glass tube, by heat sublime the sulphur and any sulphuret of arsenic. In the minimum of sulphur remain the sulphurets of bases 30 and 31. This minimum treat with test 26, next dilute; add test 38; a purple precipitate proves the base 30, and the base 31 when the liquid is troubled and a brown precipitate appears. [g] That portion of the precipitate ([a]) may contain bases 21 to 27, and must be treated by the processes IV. A (2).

B. By processes IV. B. ascertain the presence or absence of fixed bases.

When present, [a] alkalinise with test 2, add test 13; a precipitate is in 20 to 9, also in 8 to 5 when with acid 6 or 7, or a metallic base is combined with

13. Employ the proper acid for digesting the precipitate. [b] The acid solution filter (warm, when employing nitric acid); add test 24; a precipitate is sulphurets of 6 or 5 (or 7 when in excess); filter, wash the precipitate; whatever dissolves is base 7, which test 7 or 8 will verify; the residue is 6 or 5, which by the blow-pipe flame discriminate, as previously directed. When no phenomena indicate base 6, 5 only is present, as also it may be along with 6. [c] The precipitate boil in test 3; after 24 hours' repose, decant the liquid, and to the deposit add test 26, to which add test 23 for base 5, and for base 6 test 24. [a] Take liquid from filter ([b]); add test 2 to alkalinise; a precipitate is base 20 or 9 (or 8 when with acid 6). [e] This precipitate digest in test 1, which will dissolve base 9, but not base 20, or base 8 with minimum of acid: filter; [f] the liquid treat with test 34, and a precipitate is base 9; [g] the deposit ([e]) examine for base 20 by the blow-pipe; or dissolve in test 26, then alkalinise with test 2, and a precipitate is base 20; the liquid may have base 8 present, and will to test 6 supply a precipitate. The liquid ([d]) may have present bases 18 to 15, which ascertain by the processes already directed (IV. B., 1, 2), and by IV. C. examine the liquid ([a]) remaining after the precipitate. The alkalies are soluble, and need not be here regarded.

TO FIND THE ACIDS, ETC.

A. (1.) To the powder add test 26; effervescence, with a gas inodourous, prove acid 8 present, or 16 when odourous. [a] The aciduline solution (2^d) put into a test-tube, and insert a cork through which passes a thin glass tube, twice bent at a right angle (⊓); the other end place in a vessel with test 30, alkalinised by test 2, and closed from the atmosphere; the presence of acid 8 is proved by a white precipitate, soluble in test 26.

(2.) (When the compound combines base, 22, 25 or 26 with its other components, employ nitric acid and test 36; but for) any other, [a] dissolve in test 26; dilute much with water; add test 30, and a white precipitate will prove acid 1 present. [b] Treat the powder with test 25; warm; when nitrous gas evolves, and sulphur deposites, or the aciduline liquid, filtered and diluted, to test 36 supplies a white precipitate, a sulphuret is present; (if of mercury, while separating in nitro-muriatic acid, chlorine evolves, as already described, II. D.) [e].

(3.) In cool nitric acid when possible dissolve some of the compound; dilute; add test 32; a white curdy precipitate proves 12 present.

(4.) Some of the powder put in a leaden capsule, and moisten with test 24; cover with waxed traced glass; corrosion proves 13 present. By glowing coals determine the presence of acid 2, and of 11 by the blow-pipe (as before).

(5.) When 1, 7, 11, and 16 are absent, by blow-

pipe examine for acid 6. The aciduline liquids of compounds whose metallic bases precipitate by test 15, also their sulphurets, by heat dissipate test 14; by test 2 neutralise; then, as above directed, find 7 and 13, and 6 by the blow-pipe.

(6.) The alkaline liquids of compounds whose bases precipitate by test 13 (employed also for 20 to 15), by heat freed from test 14, the sulphur filter out, and treat for acid 6. More difficulty ensues when bases 9 to 5 and metallic oxides are precipitated. To enable test 15 to obtain the sulphurets, alkalinise with test 2 the earths 5, 6, 7, and 8 precipitate when acid 6 is present. Prove by tests the absence of acids 7 and 13, and the presence of 6 by the blow-pipe. When test 34 is present in the solution, acid 6 was absent, test 2 will not prove base 8, as it will 9 whether that was present or not, and as proved by the blow-pipe.

(7.) [a] When in the compound are bases 9 to 5, also 20 to 10, and metallic oxides which in aciduline solutions precipitate by test 15; [b] the powder dissolve in test 26; the metals present by test 15 precipitate; filter, by heat dissipate test 14; add test 24; a precipitate is base 6 or 5 (or 7 when insoluble on adding test 31); filter out the precipitate (and by heat volatilise test 31). [c] When bases 9 and 8 are absent, yet there are present others affected by test 13, alkalinise the liquid by test 2; add test 13, filter out the precipitated metals; the liquid treat as before for acid 6. [d] But when 9 and 8 are present, digest in test 1; the precipitate is 19 to 15 (with a spice of acid 6); acidulate with test 26, and add test 30, a precipitate is sulphate of barytes; filter, add

test 2, a precipitate is phosphate of barytes. [e] When both 9 and 16 are present, acid 6 with them is solicited by test 1. When only the latter is present, to the alkaline liquid add test 13, and the precipitate is base 16; and by the usual method ascertain that acid 6 is present or not; or, when the former alone is present, add test 5; effervescence and a voluminous precipitate prove that the base is 9; [f] the precipitate dissolve in test 26; then add test 1 till all the precipitate which first appears is re-dissolved; filter, add silicate of potash, and the very sluggish precipitate is base 9 with acid 9; filter, and add muriate of lime, and phosphate of lime will precipitate when acid 6 is present; or, [g] liquid ([e]) acidulate with test 26, alkalinise with test 2, and add muriate of lime, the precipitate will be as just named. ([h]) When both 9 and 16 are in the liquid ([e]) add test 13, the precipitated sulphuret of zinc filter out, and heat till free from test 14; the liquid treat as above for base 9 and acid 6.

Class VI.—*Mixed Compounds insoluble in Water and Acids.*

TO FIND THE COMPONENT ELEMENTS.

The refractory residue of compounds already subjected to the previous processes, and which are indifferent to the potency of dilute muriatic or nitric acid, will consist of either chloride of silver, protochloride or sulphuret of mercury, or sulphates of barytes, strontian, lime and lead.

(1.) [a] In a glass test-tube heat some of the insoluble residue; when it sublimes, unaltered, it is only either protochloride or sulphuret of mercury (the former black, the latter red, in ammonia; and globules prove the presence of some other free base or metal). [b] The portion which does not volatilise may be chloride of silver, or sulphuret of lead, lime, strontian or barytes. In a proper crucible this portion mix with thrice its weight of carbonate of soda, and fuse. When cool, soften in water, then add more water, and digest thirty minutes; filter, acidulate with test 25. By test 36 prove the presence of acid 1, and by test 32 find any chloride of sodium present with chloride of silver. [c] The contents of the filter may be carbonate of bases 5 to 7, and 22, with metallic silver when the chloride was present. Fusion may form the silver into a bead in the crucible, and the portion not fused may be extremely comminute in the aqueous liquid. When neither silver nor carbonate of lead is present in test

26 (or when present in test 25), digest the filter and its contents, and in the latter case add test 26; —a precipitate will be base 25. [d] The aciduline liquid filter, add test 2; a white precipitate is base 22. When both 25 and 22 are present add test 15; the precipitate treat with test 2; filter out base 22, and add test 26. [e] To the liquid ([e]) in a leaden capsule add test 23, and allow time for base 5, or tests 28 or 24 for base 6 alone, or with 7, which immediately precipitates; filter it out; the liquid alkalinise with test 2, and by test 8 precipitate 7 when present. These three, 5, 6, 7, discriminate as already directed, 1. C. 2.

(2.) By the blow-pipe ascertain the presence of any metallic oxides, also of acids 6 and 11; or of 11 alone, digest the powder in test 24 in a platinum crucible till separated; then add water, and treat as before directed (6). This will not dissolve bases 22, 7, 6, 5.

In reference to the non-metallic substances *Chlorine*, *Bromine*, and *Iodine*, it must be understood that when a small bead of mic. salt and deutoxide of copper is treated with a small portion of the powdered substance, the blow-pipe flame will produce a fine blue assay for the first, a green-blue for the next, and an emerald-green for the last. *Berzelius.*—Further. The powder mix with test 24 in a test-tube, and heat; when there is effervescence, and a glass rod moistened with test 2 on being held nigh causes white vapours, the powder is a chloride; or a bromide when the gas which evolves is offensive and yellow, with sulphurous acid gas also evolved; and when it is violet, also with the last gas, it is an

iodide. When the first is in excess test 32 causes a white flocculent precipitate; when the substance is either of the others, digesting in test 25, with yellow vapours and the brown solution; or yellow-brown solution and violet vapours distinguish the bromide and iodide.

For *Fluorine* in *Fluorides* the powder recently moistened with test 24 is put into a leaden capsule, then covered with the traced glass and carefully warmed, but not so much as to melt the wax; it is then left to cool, and the glass is cleaned, and when exposed the traced lines exhibit where the fluorine has solicited to combination the silicic acid of the glass. Or, the moistened powder is laid on the glass ten or fifteen minutes, and then cleaned off. For *Sulphur* in *Sulphurets* to the liquid add test 26, and effervescence, while the offensive gas (test 14) evolves, prove the sulphuret; and test 13 will act upon it however combined.

Whoever is wishful to make discoveries in this science, to add to the general stock of knowledge (and I indulge a hope of this in reference to many of my readers), must constantly keep in remembrance that by correct and more extensive information concerning subjects, by superior skill in applying the resources of the science as it at present exists, and by more dexterous manipulations in current processes, and appropriation of others which circumstances may create, with indefatigable attention to every condition of each respective combination, he may reasonably expect to equal, and in some instances may surpass, his predecessors and contemporaries.

When the quantities first employed are carefully registered, let there be a constant reference to the numbers in the tables assigned to the respective substances, and the acquisition will be greatly facilitated of the knowledge of the precise proportion or quantity of any *third* substance needed to be added, to separate the elementary components of some other substance in the menstruum, solvent, or liquid used, and likewise the proportions present in the fresh compound, as well as in such menstruum.

There is a possibility that occasionally, because of inexpert manipulation, the results obtained by the student may not be precisely as those detailed. This, however, must not discourage him to cause discontinuance of research; but rather let it excite to patient repetition of all the steps of the process, and sedulous attention to ascertain how and why the differences arose. Let not the steps in any instance either anticipate or supersede, but constantly supply, correct knowledge of particulars, to determine the existence of a common type, by which facts may be generalised, and to warrant general conclusions. There is a possibility that while steadily pursuing one analysis through all its ramifications, reasoning on one, or analogy, may suggest others, whose results supply such additional control over Nature's productions as to render them, even although not very valuable, much more interesting than those by which they were suggested.

PARTICULAR ANALYTIC PROCESSES.

HERE I assume that the student has already (as before directed) dissolved in muriatic acid, and noticed the tints caused by some powder of a substance conjectured to be adapted for being useful in the manufacture, and that he is wishful to know as well the *respective component elements* and their *relative proportions.*

A. (1.) With a temperature of 110° Fahrenheit applied to a platinum capsule, covered with paper or a Wedgwood-ware evaporating dish (for nitro-muriates or chlorides), but not of glass, evaporate dry the muriatic solution; but as it becomes gelatinous, carefully stir with a porcelain biscuit rod, or a platinum spatula, to prevent any loss by spirting, and continue until all odour of muriatic acid is dissipated, else the water to be subsequently added will dissolve a portion of the silica. Raise the temperature, during ten minutes, to 212°. When completely dry, often will there be present undissolved in the water bases 8, 9, and 20 without acid.

(2.) To the dried powder add test 26; cover with a glass plate during 24 hours' repose; add ten times the bulk of pure water, boiling hot, which will solicit every substance present except the silica, which filter out, wash well with boiling water, and save all the washings, as well as the filtered liquid; the filter dry, and calcine the contents. Verify by the calc being whiter than the dried mass, not soluble by digesting in test 26, which is not discoloured by

it; fused on charcoal with equal weight of soda, the blow-pipe assay is a transparent colourless glass; boiled with four times its weight of carbonate of soda, it forms a colourless transparent liquid, gelatinous when cold. Any other phenomena indicate defective analysis, and demand the repetition of the first process with the hydrate of potash.

B. (1.) [a] The filtered liquid and the washings evaporate to one-fourth of the bulk; alkalinise with test 2 (or 3 and boil fifteen minutes, when 15 or 33 is present; or with test 13); cover close with a glass plate; the chlorides present will precipitate, except those of bases 5, 6, 7, 8 (because solicited by the alkali), and 15. When 20 is present, it might remain in solution; bases 16, 17, 18, and 24 mostly remain solicited to combination by the test 2. [b] Closely cover the liquid during 24 hours' repose; then filter as quickly as possible without the action of the atmosphere, and wash well with boiling water, to preclude formation of carbonate of lime.

(2.) [a] To the filtered liquid add test 15, and any precipitate determine by the blow-pipe. [b] Add test 28; a precipitate will be base 5 or 6, which discriminate as before. [c] Add test 7; a precipitate will be base 7, and when this is filtered out and washed, evaporate the liquid to one half; then [d] add test 6, and a precipitate will be base 8.

C. (1.) [a] To the precipitate B. 1 [b] add test 1 in a platinum capsule, and digest at 160° for thirty minutes; the test solicits to combination base 9 (and 10) present; filter. [b] The liquid acidulate with test 26, and to separate the bases last mentioned add test 5 till alkaline; filter out the precipitated

alumine, wash, dry, and ignite. [c] Boil ten minutes, or till the odour of ammonia be almost dissipated, and the liquid is milky; then cool, during which base 10 when present will precipitate as a white powder, which filter out, wash well, dry, and ignite. When excess of the test 5 is employed, the small portion of alumine dissolved will trouble the liquid, when even a long time boiled. [d] When bases 9 and 10 are obtained by ([a]), to the liquid ([b]) add test 5, when base 12, 13, or 14 is present, and a white precipitate will fall, that is thus discriminated: the air renders 13 yellowish, which results from ignition in 12, and is white for 14. [e] When there is an insoluble residue, to it add test 26, and allow twelve hours' repose; whatever remains insoluble will be silica, or titanium, or columbium, which discriminate by the blow-pipe, as the colour of the assay, when the precipitate has been fused with mic. salt, will be a white, or yellow, or brown, for each respectively.

D. (1.) The residue of B. 1 [a] digest with test 24, at least one hour; evaporate dry; heat to dissipate the excess of acid; then stir into a quantity of water, and filter out the sulphate of lime, dry and ignite it. If sulphates of magnesia and the metals be present, they are soluble, and must be obtained, as already directed, or by subsequent processes.

(2.) [a] The dilute liquid acidulate with test 26; add test 4, or 5; filter out and wash well the precipitated bases 18, 20, or 33, which discriminate as usual, the excess of carbonic acid keeping soluble bases 8 and 15, when present. [b] Or add test 2, and filter out bases 15 and 20 when present, carefully

stirring in the test till a little of the base 20 appears at the bottom of the glass jar; then add test 16 to precipitate all the iron. [c] Add test 3, boil, and filter out the base 15; or, if with 8, [d] add test 13, filter out base 15, which by heat free from test 14. [e] Add test 6 and test 2 in equivalence, and there will be two precipitates of phosphate of ammonia and magnesia. [f] The filtered liquid heat to 200° for ten minutes, and base 14 will precipitate (also when test 2 is added); filter, dry, and ignite. [g] The filtered liquid gently boil, and add test 1; filter out base 8, wash well, dry, and ignite.

E. (1.) [a] The filter and its contents (2 [a] above) digest in test 25; neutralise with test 1; dilute the liquid to ten times its bulk, and filter out the precipitate bases 20 and 18. [b] Evaporate the filtered liquid to one-fourth; acidulate with test 26; raise to 160° for seventy-five minutes; filter out base 33, wash well, dry, and heat till the whole is green. [c] The precipitates ([a]) dissolve in test 26; dilute to ten times the bulk; carefully add test 2; filter out base 20, wash well, and dry. [d] The liquid evaporate dry, heat the residue to volatilise the test 2, wash well and dry the base 18. Or, [e] To the solution ([c]) add test 2, and instantly filter; soon does the liquid appear troubled and discoloured, and in twenty-four hours the base 20 is obtained. [f] To the contents of filter (E. 1 [a]) add equal weight of nitrate of potash, put into a platinum crucible, cover close, and fuse. The chromic acid solicits to combination the base 1; the manganesic acid similarly solicits the portion of the oxygen not appropriated by the iron; and when the calc is well mixed in pure water, during twenty-

four hours both bases 15 and 20 precipitate. [g] The filtered liquid evaporate till the pellicle appears; then place aside on a support to crystallise. [h] The filter and its contents dissolve in test 26, dilute to ten times the bulk; slightly alkalinise (to restore the litmus paper after being affected by acetic acid) by gradually adding test 2; filter out base 20; add test 9; filter out base 15, wash well, dry, and ignite to incandescence.

F. (1.) [a] Weigh most carefully each product (most proper as soon as it is cool after being ignited, because then free from atmospheric action), and determine the total sum. The consecutive processes induce losses, more or fewer as the number of components, from ·5 to 2 per cent.; and in this ever does each component differ from the others. Whenever the total sum is within 2 per cent. of the first weight, the analysis may be regarded as satisfactory; but when a larger portion is absent, there is proof that some alkali or volatile component (probably fluorine) was proximate, but evolved without being regarded. [b] Careless washing may cause the total to exceed the primary weight, and such culpable inattention is a subject of reprehension as well as regret. Avoid it most sedulously. But this excess may be consequent on an oxide receiving additional oxygen, which, of course, must be noticed and subtracted. Also it may be found to be owing to the formation of a basic salt, while a precipitate resulted, and which salt was not decomposed during the calcination or heating prior to weighing. And whenever substances are examined which do not

chemically combine agreeably to combinative potencies.

G. (1.) When the presence of an alkali is suspected, [a] In a porcelain retort, with a refrigerated receiver, incandesce for 30 minutes a determined weight of the mineral in coarse powder, and hereby will be obtained the water and all volatile components. When this process does not alter the weight, certainly either alkali or acid is present. [b] A portion of the mineral powder mix with six times its weight of carbonate of barytes, and in a platinum crucible calcine during two hours. [c] The calc dissolve in test 26; separate the silica by A. 2 and base 5 by test 24. To the filtered liquid add test 5, filter, and wash well. The liquid evaporate to a fourth; add oxalate of ammonia, and filter out base 7, dry, and by heat dissipate test 2. The residue will be an acid sulphate with an alkaline base, which determine by the processes already mentioned. Or,

H. (1.) [a] The mineral powder 1 portion, and powder of fluor spar 2 portions, moistened with test 24, place in a leaden capsule, and heat to 100°, carefully avoiding the active poisonous gas which will evolve, and which is fluoric acid gas combined with the silica; the excess of test 24 also is dissipated. The affusion of pure water will separate the soluble salts from the sulphate of lime, and readily afterwards will the alkali be found in the sulphate. [b] When fluor spar is supposed to be present, add test 23. Any residue after the solution in test 26 can be thus treated. To the fluoric solution add test 24, evaporate dry, calcine to low red heat and

dissipate the test 23, especially when present with base 7. Or,

I. (1.) The mineral powder 1 portion, and test 36, or boracic acid 6 portions, fuse during two hours in a porcelain crucible. The calc dissolve in test 26, dilute to twenty bulks with boiling water; evaporate dry to dissipate excess of acid. The residue stir well into pure water, then filter out the silica (also the boracic acid when employed). The liquid evaporate to a fourth; add test 5, and filter out bases 7, 8, 9, when present; evaporate dry, and by heat dissipate test 2. The contents of the capsule dissolve in test 24, dilute much, evaporate and crystallise for base 1. Add test 30, and any other alkalies present will precipitate; filter, evaporate dry. In test 31 digest, to separate base 3, the others precipitate, and can be filtered out. The liquid should next be evaporated, and the base 3 be dried and ignited.

K. (LOWITZ'S *method, the first published.*) In a silver crucible put the mineral powder 1 portion with 3 of pure hydrate of potash; moisten with pure water, and boil dry, add a like quantity of water, and again boil dry, and the addition of water must be repeated as needed. When during the ebullition bubbles large and tough are formed, the process is drawing to a successful termination. The calc must then be well stirred into plenty of pure water, and the components separated as usual.

L. (SCHRADER'S *method.*) The mineral powder moisten with test 1 or 3; put into a platinum crucible and calcine one hour; mix well in plenty of pure water; evaporate to a fourth; acidulate with

test 26; again evaporate dry; the result dissolve in a soda ley at the common temperature; again acidulate with test 26; dilute, evaporate, filter out the gelatinous precipitate, dry, and ignite the silica.

M. (DAVY'S *method.*) The mineral powder 1 portion mix with 2 portions of boracic acid, and in a silver or platinum crucible, covered, calcine forty minutes. Add test 25, 3 portions, and water 16 portions, and digest till all is in the liquid; evaporate to a fifth of the bulk; filter out, and well wash the silica, dry, and ignite. The filtered liquid with the washings, evaporate to a fourth; alkalinise with test 5, and boil until precipitation ceases; filter out, and by the usual processes discriminate the contents of the filter. The liquid acidulate with test 25, and evaporate till all the boracic acid is precipitated; filter it out. The liquid evaporate dry, heat to 450° Fahrenheit, to decompose and dissipate the salts of base 4, and leave those of base 1 and 2. The alumine will be supplied by test 1, lime by 24, iron by 16, magnesia by pure soda, and manganese by hydrosulphuret of potash.

N. (THOMSON'S *method for pure Silica.*) In a platinum crucible liquefy equal weight of carbonates of potash and soda; carefully add the powder (ground dry flint) till effervescence ceases by all the carbonic acid gas being dissipated; then cool, and in test 26 dissolve the calc; filter, evaporate dry; add test 26, digest three hours; then dilute with twenty bulks of boiling pure water; filter, wash well, evaporate dry, and ignite the silica.

O. (1.) "When a mineral of few component elements has much of base 7 present with little of

bases 8 and 9, boil the aqueous solution one hour, to dissipate the carbonic acid; add test 2, and filter out those bases; wash well, dry, and dissolve in acetic acid; filter out, wash, evaporate dry, and ignite base 8. To the liquid add test 2, and filter out base 9, which treat similarly. Or, in test 26 digest the precipitate one hour; dilute four bulks; add test 3; filter, evaporate dry; dissolve in test 26; dilute; let repose one hour, filter out, wash, dry, and ignite base 9; base 8 obtain as before.

(2.) When only a little of base 7 or 5 is present with much of base 9 or 8, to the very dilute solution add test 24 (or 7, when only base 7 is present), and filter out the precipitate. When both 5 and 7 are present add test 24, and evaporate to a fourth; decant the solution, and add 500 bulks of water; the base 5 as a sulphate precipitates, and must be collected on the filter as usual.

(3.) [a] When little of base 9 is present with much of base 8, to the solution raised to 180° (not boiled) add carbonate of magnesia till precipitation of base 9 ceases; then while very dilute instantly filter out before the sulphate of magnesia can mix with the base 9. [b] When little of base 8 is present with much of base 9, by test 2 precipitate all present, and the precipitate treat with acetic acid, and filter out base 8.

For the Relative Quantities.—(BERZELIUS'S *method.*)

IN this I assume that the muriatic solution is freed by filtration from silica.

A. (1.) The acidulated liquid with the washings pour into a glass jar sufficiently large to prevent loss by effervescence, and cover with a glass capsule. Gradually add test 4, or 2, and bases 9 and 2 will precipitate, which filter out and discriminate; any of bases 7 and 8 present will remain in solution as bicarbonates.

(2.) [a] The precipitate wash well, (when test 4 is employed, we cannot either dry or calcine it; and the weight of base 9 must be determined by subtracting that of base 20, because with base 9 is test 3 insolubly combined). The contents of the filter remove, and the filter itself wash with test 26. [b] The filtered mass digest in test 1; base 20 precipitates; filter out, wash, dry, calcine, and weigh. [c] When base 15 is suspected, this precipitate, prior to weighing, again dissolve in test 26; then alkalinise with test 2; the base 20 precipitates, which treat as already directed. [d] The alkaline liquid acidulate with test 26, which will hold in solution base 9; add test 5; the precipitate (to find whether silica is present or not) filter, wash with boiling water, dry, calcine, and weigh. [e] When test 34 is used, muriate of potash is formed, base 9 precipitates, and base 4 evolves; but excess of this dissolves much of base 9, which gives up the other only by evaporation, and may induce loss in the calculation. Besides, excess

of test 2 may precipitate some of the base 1 with base 9, and deceive in the quantity of the component. But test 5, by leaving free carbonic acid in the liquid, precludes the combination of the bases 9 and 1.

(3.) The bases 7 and 8 present as bicarbonates in the solution from which the bases 9 and 20 have been abstracted, may be obtained by different processes. [a] The solution acidulate with test 26, which will dissipate the carbonic acid, leaving present in the liquid a slight excess of base 4. Add oxalate of ammonia during appearance of precipitate, and after many hours' repose for the separation to be complete, filter out the oxalate of lime, wash, dry, and calcine with the filter in a crucible covered, and placed obliquely over the lamp ; a thin iron band on the inferior edge interrupts the current of heated air, and promotes the ingress of atmospheric air to carbonate the lime ; occasionally it is moistened with test 5, dried, ignited, and weighed. The lime is calculated from the proportions in carbonate of lime. [b] In a glass matrass boil two hours the filtered liquid and the washings ; add test 3 ; when the precipitate has reposed twenty-four hours decant the clear liquid, filter the precipitate, and well wash the filter. The liquid from the filter evaporate dry ; wash with boiling water, which will leave a fresh portion of magnesia undissolved. Test the liquid, and if not alkaline, render it so, and again evaporate dry. The magnesia or the filter wash with boiling water as quickly as possible, for $\frac{1}{9000}$ dissolves in the water ; and if cold water be employed the filtering is slower, and the solubility is $\frac{1}{2500}$. The magnesia calcine, weigh, dissolve in test 26, evaporate dry ;

again dissolve in water slightly acidulated with the test 26. There will remain an observable portion of silica, always most noticed with bases 8, 15 and 16. Or,

(4.) [a] The liquid alkalinise with test 3, evaporate dry, then add plenty of pure water, which will leave separable the carbonates of bases 7 and 8, which filter out, wash well, moisten with test 24, and heat to incandescence, and weigh. The solution has present the sulphate of lime dissolved with the sulphate of magnesia; the sulphate of lime calcine, weigh, deduct its weight from that of the two sulphates, and thus determine the weight of the sulphate of magnesia. The proportions of the two bases appear from the components of the salts. Or (*less correct*),

(5.) The liquid treat with oxalate of ammonia, filter out the lime; add test 6 to the muriatic solution of magnesia (the simple neutral salt is not precipitated); wash, calcine, and weigh the precipitate. Or (*best*),

(6.) With test 3 precipitate base 8, or evaporate the liquid dry, and calcine the salt; on adding water the base 8 is not affected.

When base 15 is suspected, or present, add test 13, the precipitate filter out, dry, and dissolve in test 26; dilute, add test 3; evaporate dry; digest in water; filter, wash, dry, and calcine, and ascertain that silica is absent. Or, add test 9; precipitate; dissolve in test 34; the precipitate calcine, and determine the results.

Those distinct components of the respective compounds, separable without decomposition into the elements—as flint, clay—are the *proximate*

or immediate principles, whose resolution into their simple components constitutes their *ultimate analysis.* In the prosecution of this, of greater importance is the formation of a habit of calculation, and a facility of manipulation, than to save time by using tables, sliding rules, or logarithmic scales. Let the student always, at commencing any process, carefully notice whatever he is likely to need, then examine the phials which contain the elements, and see that every article required is present, and in a proper state. Whatever researches he undertakes, the grandest results are utility and the application of scientific principles to the several Arts. Purchase only those articles of apparatus you cannot possibly make yourself, nor anything new, when you can effect the process with those already in store. Conducting the requisite processes to form those indispensable will be as well an introduction to the technicalities and the application of the various implements as it will induce facility of manipulation and confidence in the results. The working model of the mechanic exhibits the economy of power in its construction ; the projected model of an edifice exceeds the paper plan of the architect, and both at a comparative trifling expense ; and the experiments of the student, equally as cheap as intrinsically useful, supply accurate information. He who thus learns to select the most simple method to effect his purpose—who reflects, that whenever discrepancies appear in results most probably they are consequent on some component present in the compounds, change of temperature, or other conditions not contemplated in the general detail—will seldom miss the high gratification he

anticipates. But he who purchases all articles, and those in particular named re-agents, or tests, will ever remain only an half-and-half student; one degree above the mere reader of systems of chemistry, but many degrees below the standard of a real practical chemist.

For repeated mention of the processes to obtain the element silica, I shall not be censured, as the singular fact of rendering it soluble in the acids is one of the discoveries most contributive to accuracy in analysis, and is now an indispensable condition, especially in that of minerals, approximating nigher to truth than was previously imagined. No mineral now is regarded as ready for further manipulations until completely soluble in acids; and when the acid alone is inefficient, previous fusion with an alkali is adopted, employing a silver or platinum crucible when the mineral is earthy, and when it is metallic one of porcelain. Uncertainty results from the needful repetitions of filtration and evaporation; and when a minute portion of the substance is employed, or important consequences are involved in the determination, there is indispensable a degree of care and attention much greater than in ordinary investigations.

Although so very recently have been applied to the Arts of Life the agencies of Chemistry, yet, by the splendid series of discoveries, man is enabled to so operate on all the various forms of matter with which he is surrounded as to cause all in turn to administer to his wants or his luxuries. The details of the gradations of ingenuity in any important Manufacture, directs to the chief and primary

purpose an acquaintance with its scientific principles, elucidatory of obsolete productions, and of the excellence of others more recent, and suggesting the *ne plus ultra.*

The traditional practices of Metallurgical Chemistry continue, and current knowledge thereof on scientific principles is proportionately trifling, imperfect, fragmentitious, not dissimilar to isolated brilliant points thinly scattered as lucid specks on an extended hemisphere of darkness. Therefore every research undertaken in this domain almost certainly will produce some interesting facts, and lead forward to some important consequences, far beyond what was first contemplated.

I have not glanced at the prevalent theories of the Science. Nature laughs at them, and by extraordinary developments at her pleasure compels us to acknowledge ourselves her vassals, who vainly strive to subject her operations to the laws we have laid down. Chemists will ere long cease to "halt between two opinions," because of the natural libration of human opinions—now in favour of Stahl, and his imponderable element common to every combustible substance; then of those of Lavoisier, with his ponderable element. Science seeks only the fellowship of Truth; she leads her votary from the dark and secret cell into the bright sunlight of philosophy, unfolds to his view, and commands him to become "the servant and interpreter" of—the wonderful Book of Nature, of whose contents EXPERIMENT only is the true index.

The domain of Nature is boundless, vast, and wonderful; but prejudice bars up the gate through

which alone we can enter to obtain sound knowledge. He who would possess this must disregard the timidity which shrinks from opposition to his exertions, and despise that tyranny of opinion which condemns their objects. Wisdom, like beauty, can be won only by the bold; and he who pants for immortality and the fame of generations unborn—a desire ever the strongest stimulant to the rightly ambitious—he whose talents are capable of bettering the condition of his fellow-men, must crush the barrier of custom and opinion, must boldly soar to the accomplishment of mighty purposes, must resolve to leave mankind wiser than he found them, and "posterity will do him justice."

If the remarks herein promulgated be founded in truth, their publicity will introduce a rigorous accuracy and certainty into the manufacture of which it has been imagined incapable. There are exhibited harmonious analogies in the general laws and constitutions of related objects. The Manufacturer may apply the mathematics to his chemical investigations, and like the geometrician, by calculation, rectify the unavoidable errors of his manipulations, and eliminate from the essential elements of a compound those products of its analysis whose quantity cannot be reduced to any admissible proportion.

CHAPTER II.

TEMPERATURE.

TEMPERATURE of a substance is its condition relative to recipience and fixation of heat—the momenta of the motions of atoms as nuclei and their orbital spaces, compared with like action on some standard, or well-known substance, as the thermometer. And our perceptions of the recipience and fixation, as compared with their action on ourselves, we indicate by the general correlative terms, *heat* and *cold*. And the *specific heat* or *cold* is strictly the precise sum of the momenta appropriated by the atomic orbital spaces, needful to render different substances of the like temperature. With similar conditions we expect the atoms of substances respectively to appropriate, or evolve, like temperatures; and as the momenta are accelerated, or retarded, the condition will be superior, or equal, or inferior to the force of cohesion, and the compound will be a gas, or a fluid, or a solid. That the elementary atoms have like specific heat (although we remain without proofs because of either unavoidable or unnoticed errors in the experiments) seems very probable from the approximating results of different metals; for

instance: those of lead and nickel are ·0293 and 1035; their atomic weights 26 and 7; then 1 : ·0293 :: 26 : 7618; and 1 : 1035 :: 7 : 7245; ♌ 373.

The alteration of the orbital spaces of atoms, very probably is Nature's most secret manner of operation, as the researches of man have ascertained little with regard to the laws that govern its variations in this succession—metals, stones, glass, wood, charcoal, feathers, silk, wool, hair.

Substances are solicited in two peculiar modes: one (essential to cohesion in the usual condition subjected to the general state of the atmosphere), their inherent combinative potencies, which cause them to remain chemically the same substances by the reciprocal actions of their atoms and orbital spaces; the other, the fixation of oxygen by the general motions of heat involving the preceding, disturbing those orbital spaces, and by either giving polarity to the atoms or rendering one of their sides positive and the other negative, capacitate them for chemical combination with others. Substances have essential inequality in the like bulk, because of which the same momenta of the motions of heat differ in effect, the same impulsive force produces unequal velocities, in disregard of accidental circumstances, as probable difference of figure of atoms, and of space for obtaining the results. Hence the same substance, under like conditions, in equal weights appropriate equal momenta of atomic motions or heat, while equal weights of different substances vary greatly in this appropriation.

The alteration or variation of the relative distances of the atoms of substances, because of the

orbital spaces being more or less dilated, is the property signified by the term *conducting power*, and causes *expansion*, differing according to continuity, density, dispersion, irradiation, and the degree in which the motions are fixed and again evolved; while the *capacity for heat* signifies the relative capability of substances in proportion to the size of their atomic orbital spaces, to appropriate and fix the motions of oxygen; in this succession metals have chief capacity, liquids less, because dispersed by heat, and gases least, because expanded by it, and in them it is exhausted. These properties constitute all which are implied by the poetical correlative terms—*Attraction* and *Repulsion.**

* The *conducting power* of gold being 1·000, that of silver is ·973, copper ·898, platinum ·381, iron ·374, zinc ·363, tin ·304, lead ·180, porcelain ·122, flint-ware ·116, clay ·112. Their *capacity for heat* is inversely as the numbers—gold ·5, silver ·082, copper ·112, platinum ·130, iron ·145, zinc ·102, tin ·06, lead ·04, porcelain ·006, flint-ware ·005, clay ·002. Their *melting recipience*, gold 5237, silver 4717, copper 4587, platinum 23177, iron 21637, zinc 700, tin 442, lead 612. Their *appropriation of oxygen*, gold 1· and 2·, silver 3·5, copper 2·5 black, 12·5 red; platinum 1· and 2·, iron 28·75 black, 48·12 red; zinc 32·12; tin 23·5; lead 11·53 red, 15·384 brown; antimony 18·6; manganese 28·75 and 57·5; from slightly aciduline solution, or water, or combustion with nitrate of potash; alumine 47·, potash 20·5, soda 34·5, barytes 10·5, lime 28·, magnesia 37.

The experiments of Lavoisier and Laplace determine the expansibility of the several kinds of glass, which at 32° Fahrenheit are 1·00000000, to be in these ratios at 212°: 1·00081166, 1·00089089, 1·00087572, 1·00089760, 1·00091751; and by Gen. Foy at 1·000080787. Then, as permanent glass will thus expand, no wonder that the alternations of temperature cause crazing of the soft glazes which cover our wares. By Mr. Daniell's register

By the fixation of oxygen the orbital spaces of the atoms expand, and when a certain degree of temperature is attained, their reaction places the atoms farther asunder, supersedes the reciprocal potencies of the particles among themselves, the crystalline or cohesive structure, in proportion to the acceleration and momenta. These exceed in substances with raised temperature those in others which are lower, and instantly much above those needful to commence the motions. The times of evolving, and the precise alterations of capacity, might assist us to solve the problem of the *absolute quantity present* of the motions; only we are unable to determine their *absolute absence.*

Those substances whose orbital spaces of atoms so readily expand as no longer to be aggregated, but by the current processes of raising the temperature become mobile, separate, and in all directions slide over each other, are called *fusible,* and their condition is that of being *metalled,* melted or fused; and others not thus affected are called *infusible.* The natural condition of substances seems that of solidity from low temperature, and the accidental condition fluidity from raised temperature, when fusion precedes decomposition.

pyrometer, Wedgwood's queen's-ware has linear expansion agreeably to a fixed law; at 212°, 1·000735, and at 662°, 1·002995; precisely the same as platinum; but this alters when it is fused. These experiments prove that the ingenuity of the philosopher-artist has been successful in constructing a pyrometer, with sensibility to expansion by heat, of *one one-hundred-thousandth part of an inch!*

Substances of varied temperatures, when in contact involved in accelerated motions by fixation of oxygen, have their atomic orbital spaces expanded, those most involved less so than the others, during a certain time, varied with the nature of the respective substances, but ultimately the effect is all have the same temperature, those with greatest momenta solicit those with less, and all re-act in the precise proportions of their capacities for heat.

Substances indifferent to accelerated motions in addition to what render their particles fluid are *fixed*, in contradistinction to the *volatile*, which are susceptible of such acceleration, and assume the state of gas. And those not volatile *per se*, when mixed with others which are so, in high temperatures evolve, and disengaged from tralatitious additions again condense in a solid form; thus sal ammoniac will carry iron up in vapour; and because of this property of substances, the intense heat of the potter's oven volatilises and brings into combination those particles which only for the comminution would not have readily united.

Combustion—an example of *decomposition* and *recomposition*, attended with the intermediate accessories of light and heat—is the result of the combinative potency of oxygen soliciting the hydrogen evolved while the motions of heat diffuse through a substance in which carbon likewise is present. Current knowledge, however, only compares the heat evolved with the oxygen supplied, and does not determine what proportion of the heat and light evolved results from the oxygen present, and from the recipient body.

When the atoms of oxygen, the chief positive supporter of combustion, from the state of gas with accelerated orbital motion, from primary force in right lines and the reaction of attendant atoms, are fixed by substances, these are affected by the momenta; in some instances the bulk is reduced, in others enlarged, and in others with similar capacity for heat.* Heat or excitement, as flaming paper, applied commences the combustion—of a candle for instance; the hydrogen present, excited as gas, rises in orbits too large for the space, forms a vacuum, which the oxygen fills with eight times the force, fixed by the recipient hydrogen in particles of water or vapour, and by the carbon, the atoms not consumed or electrified, in carbonic acid.† The

* Lavoisier calculated that equal fixation of oxygen results from the combustion of substances: oak wood 1089, charcoal 600, pit-coal 600, coke 403. Kirwan regards the potencies of charcoal, pit-coal, and pine wood as 57·6, 36, and 20·1. Fossombroni calculates that the combustion of wood is adequate to evaporate twice its weight of water. Coke supplies heat more regular and intense than coal, as 8 to 3, because during combustion all its substance equalises the fixation of oxygen in the maximum without any such loss of a portion of its matter, as in elastic vapour evolves from coal, with a supply of only a small portion of heat.

† *Carbon* (in its form of *Charcoal*) is the residuum of vegetables, by high temperature just incandesced, and all its volatile and factitious components dissipated; thus wood is treated in closed vessels, and the hydrogen or water is separated, and the volatile products while burning in air combine with the oxygen and form carbonic acid gas. The most pure kind is by passing through a red-hot tube the vapour of alcohol, or oil of turpentine. It is black, insipid, inodourous, insoluble in water, brittle, very pulverulent; in closed vessels not altered by heat, but a gas evolved of hydrogen, carbon, oxygen and nitrogen. The most dense kinds

oxygen is thus fixed, and decomposes a certain portion of the air ; the fixation causes an intense local heat, which escapes by propelling the atoms of air, as light, concentrating the motion, as heat, at the spot. Whatever absorbs the heat diminishes the light and the excitement ; but the process first mentioned continues while hydrogen and carbon evolve by fixation of the oxygen, supplied for the purpose. Such, likewise, will be the causes and effects, although there be promotion of the access of oxygen and varying of the circumstances.

An incombustible substance by raised temperature increases in bulk, but in air alone quickly returns to its primary state. Under like circumstances one combustible acquires intense ignition, gradually diminishes in bulk, while a stream of heat and light evolves and solicits bodies present during a change of all its physical characteristics. As each metal ignites with oxygen it is combustible, but those which do not flame in atmospheric air are not termed inflammable. The substances so termed evolve heat and light exceeding the proportion to which their densities might seem to lead, and frequently in that of their purity and perfection.

A combustible substance is consumed, or its

with greatest potency solicit the gases—ammoniacal, 90 times its volume, nitrous oxide 40, carbonic oxide 35, nitrogen $7\frac{1}{2}$, oxygen $9\frac{1}{4}$, hydrogen $1\frac{3}{4}$; and unchanged in their properties they restore them at 212°. In twenty-four hours charcoal absorbs from the atmosphere one-twentieth of its weight—of which fifteen-twentieths are water. Because of this absorbency (not yet explained) it is of great utility in the Arts.

individuality destroyed, heat and light being evolved during the change of condition, because (on Lavoisier's hypothesis) 1. Combustion of a substance occurs only when oxygen is present, whose quantity regulates the intensity. Ever must be present some supporter; yet of oxygen, different proportions may be present without any phenomenon of combustion, as this will not ensue merely from condensed oxygen. 2. Combustion always consumes the oxygen; and it ensues with compound supporters, where would fail a simple one alone, as oxygen, chlorine, iodine, etc., as when with each other, or with nitrogen. The additional proportion of oxygen which constitutes some substances supporters is separated by combustion. 3. The weight of the products of each substance after combustion, with that of the oxygen consumed, correspond with its weight prior to combustion. 4. The oxygen combined with the combustible substance can be recovered from the fresh compound, and the weight regained will equal that lost during combustion. 5. Every instance of combustion evolves light and heat, or fire. 6. In a limited volume of air only can a certain portion of a combustible substance be burned. 7. The burning of a substance renders the air present unfit to continue combustion, or support animal life.*

* Frequently have we heard disprobative remarks on the murky atmosphere of the potteries, and it becomes us to fearlessly and fairly meet the supposed disadvantage. Whoever has given proper attention to the matter is well convinced that by remaining at rest atmospheric air deteriorates; becomes not merely useless, but deleterious; like water, stagnant, stinks, becomes corrupted

Those simple combustibles whose cohesion is easily destroyed, as by melting, or which are elastic fluids, are readily inflamed; others, because of less momenta of combinative potencies, are less inflammable than some combustible oxides, and which more readily than homogeneous particles combine with oxygen or easily separate.

Only can a combustible substance solicit all the oxygen from products, or by combining with this

and unfit to nourish animals or vegetables. If this be admitted, then we may affirm that the effect on a great scale produced by gales, and tornadoes, and hurricanes, and storms is on a small scale accomplished for this district by the columns of rarefied air which daily ascend from the furnaces of the steam-engines and the ovens of the manufactories. I will allow the corrupt state of an atmosphere (were it constantly to remain) saturated with carbonaceous particles, and others brushed from the ware; the effluvia from oils and tallow heated in the application to the iron and brass of the lathes and other machines in constant motion; from the turpentine and tar of the painters and gilders, and the oils of the printers; the exhalations from the animal secretions and discharges, perspirations, fumes, and evacuations; the respirations of thousands of pairs of lungs, many of the breaths naturally not the most balmy, and with increased offensiveness from last night's debauch; these all mixed, *s. a.* form an aërial compound, neither the most grateful nor healthful, and in the compass of a very limited space give a congeries of disease only existent in a manufactory where the animal and artificial machinery are together in motion. To preclude noxious results by properly ventilating this atmosphere, what arrangements would the man of science propose? Certainly one tantamount to that existing, although disregarded. He would say, avail yourself of the agency of fire; by some long tube or funnel compel corrupted air to undergo a fiery ordeal, and escape to the upper regions; exactly that which is effected by our hovels and engine chimneys; and the whole district derives advantages from what the ignorant regard as a cause of complaint.

separate hydrogen from water, as when evolved during the oxidation of zinc, or iron filings, in a very dilute aciduline liquid. The absence of heat and light renders the oxygen of products incapable of supporting combustion; yet when these products solicit an additional proportion of oxygen, again they have the peculiar property of becoming supporters.

When all the conditions promote the complete combustion of the products, the flame is perfect; otherwise a portion, as smoke, escapes unburned, and soot results.

Assuming, as I have at p. 35, that chemical combination is a result of the different and opposed potencies of the elements or substances exhibited together, we only need to reflect and admit, that, as each substance and element ever retains peculiar permanent combinative potency, only modified by the re-action of that with which it combines; also, that those elements or substances which combine always have opposite combinative forces and momentum; also, that this remark applies to oxygen, acids, and all positive substances opposed to the negative hydrogen, alkalies, earths, and metals; and that the conditions of the union of these are exhibited as heat, light, fire, electricity, and others similar, heat and flame, heat and light, for all the phenomena of combustion to be readily explicable. As the extreme receptive potency can be solicited by other less receptive, because to a certain degree the two are relatively positive and negative, we find oxygen and chlorine form permanent compounds.

By artificial means, or electricity, we appear to collect the *pure* aciduline and alkaline principles

whose concentration, *in points*, supply the intense atomic motion, momentum, excitement or *heat* of their condensation; and also *light* by—the union of those gases in the atmosphere and the substance encountered—their combustion or dispersion of whatever is present. The knowledge of this principle of excited momenta, and its dexterous application to effect useful results from the properties of substances, more excitable than others, or which break, evaporate, silently and gradually expand, radiate, absorb, disperse, or again combine because of it, are essential to the chemist. Only by carefully regarding the endless continuity of phenomena and change in the relative and reciprocal potencies by substances acquired and exerted from the universal agent of nature, motion, can we possibly arrive at correct and beneficial conclusions.

Until the atmosphere of the oven is at 1000° Fahrenheit its particles retard combustion; therefore the nearer it approximates to that temperature by contact with some heated substance before it permeates the oven, the more successfully will it solicit and fix oxygen. The cave of the glass furnace causes the atoms which pass through it to alter their momenta, and the diminished motion of the atoms enhances their fixation in the fire. A passage is constructed for the conveyance of fuel from the open space belonging to the manufactory, and beneath the hearth of the oven forms a vaulted space named the *cave*. From this the air, in a state of raised temperature, is admitted into the furnace, there it is decomposed, the oxygen is for the greater part fixed; the azote passes out of the oven above the level of the

men's heads, and is carried up the hovel. The doors supply only the proportion of air indispensable for the respiration of the workmen, and consequently nearly all the advantages of the accelerated velocity of draught produced by the height of the hovel are appropriated by the furnace. And as every pound of coal thus consumed, in order to be completely saturated with oxygen for its perfect combustion, must have a current of air containing thrice the quantity which mere theory would assign for the purpose, and must have 20 lbs. of air, or 265·5 cubic feet (as M. Clement has demonstrated), the velocity needs to be artificially accelerated. Air itself is remarkably sluggish, more so than any other substance in conveying heat; and it is because of this that our oven-men can during a short interval bear without inconvenience the extremely high temperature of the oven while drawing the seggars, these last being so hot that thick rags are requisite to protect the hands, and yet the body is not injuriously affected. There is no reason why the potter should not improve his processes whenever the advantages of economy and utility are connected. As intense heat in the glass furnace at a constant temperature results from the adaptation of the cave, there certainly is a possibility of so adapting the potter's oven as to be benefited by subterraneous draughts. Some smelting furnaces are supplied by *red-hot air*, obtained in this manner: A range of iron pipes of large bore, from 20 to 30 feet long, is surrounded by a circular flue of brick-work, at the distance of 8 inches. While along this flue passes the fire of a furnace to keep the pipes at a red heat, the blast

engine propels the air through the pipes into the furnace, during which the hydrogen atoms are separated, and those of oxygen are fixed.

The calculations, etc., of M. Clement and Desormes have induced the conclusion that the temperature of the furnace for smelting iron is increased 270°—360° Fahrenheit by the application of the hot-air blast, which increase is regarded as adequate to the explanation of all the observed effects.

The principle itself obtains in the construction of the potter's oven. A number of small apertures, or vents, whose areas are exactly equal to that of each *bag*, are adapted to promote the equal distribution of the fixation of oxygen throughout the whole interior of the oven itself, usually being placed above the mouths that the air admitted may obtain the high temperature without cooling the seggars affected.

There is a great necessity for solving the problem—What degrees of temperature must be supplied to the respective kinds of ware, in baking biscuit or glaze, to render each permanent in ordinary alternations? Hence the potter should be accommodated with a pyrometer by which he may ascertain the high temperatures in his oven, and be able readily and accurately to read them off on a determined scale during any period, or the whole, of any baking process, that he may thereby possess a greater degree of certainty than at present, in reference to the employment of fuel.

About a century ago Mr. Ralph Shaw, of Burslem, while using mixed clays to form his

"*patent*" pottery, noticed the different tints which the same body acquired by the several degrees of temperature in the various parts of the oven. The application of this principle by John Mitchell to regulate his baking process, and thereby render his wares superior to others, was one cause of Shaw's action against him for alleged infringement on his patent.* The extension of the principle to regulate all the processes by (*trial pieces*, in the parlance of the workmen, or what I shall call) *pyrometrical beads* was by the brothers Thomas and John Wedgwood, at a time when the party, to whom because of the *name* all the merits of this and their other improvements have been assigned by some philosophical journalists, was not more than ten years of age. The *beads* they introduced, and which are still employed, are much similar to a small poppy head, out of which has been cut the calyx.

Scarcely does any person need be told how very indeterminate in regard to temperature are the expressions a *red*, a *bright* red, and a *white* heat.† Even were these three conditions most plainly and

* This action was tried at Stafford, in July, 1736, all the Manufacturers bearing a portion of the expenses with Mr. Mitchell, and those of that day most respectable were present in court. A most intelligent and completely disinterested special jury nonsuited the plaintiff; and the learned judge thus concluded his announcement of their decision: "Go home, potters, and make whatever kinds of pots you please; only do make them."

† As indicated by Wedgwood's pyrometer, the respective temperatures of these metals, copper at 27° melts, iron at 90° welds, cast iron at 130° is in fusion, or runs among the fuel 150°; yet to each as to all we apply the term *white* heat.

obviously distinguished from each other, the terms have much latitude of application, for the brightness and the luminousness of incandescence increases with the fixation of oxygen, through the numerous gradations, which cannot be indicated by words nor discriminated by the most experienced eye. To the philosopher-chemist, who reasons on the difficulty of perfectly describing by words the ideas of colours —that the differences in visual powers, and in the lights by which pyrometrical beads are examined; also, that the very slight difference of many tints, as well as the presence of vapours floating in the interior of the oven are likely to preclude just determinations—the employment of such beads may be liable to many and insuperable objections, and especially when we take into the account the slight differences of spicing of iron, which affects the alumine of common clay, and the consequent variation of tints that will be presented by pyrometrical beads of different kinds of clay baked together at the same time, and others placed in different parts of the oven. But the fact is indisputable, that the fireman, by the tints of these beads, with great precision discriminates the varied heat of different parts of the oven during the baking process, either biscuit or glaze, and accordingly regulates his supplies of fuel. Concerning the progress of this process, often is the experienced eye of the fireman able to render available the different appearances presented by the interior of the oven, and the tints of the trials, and even independent of these, not seldom will he come to just conclusions when the fuel is of one kind. And this on the same principle, as only those persons

who are accustomed to examining objects through a telescope can easily and readily avail themselves of its services.

The observation, that in the highest degrees of noticed temperature some particularly pure clays had contracted in volume, more than one-fourth in every dimension, appears to have suggested the application of this principle as likely to be a more accurate measure of heat, than the different tints of colour. The diminution in bulk of alumine, and the compounds of which it is a chief component, gradually and regularly by different degrees of raised temperature, from its commencement at the low red heat just visible in daylight, till the whole is vitrified, therefore, at the highest degree sustainable by crucibles and seggars, is one of those evidences whose depositions need to be most attentively and scrupulously investigated.

On this principle, however, is founded the ingenious pyrometer which Josiah Wedgwood announced as his invention, but others claim as that of Thomas Massey, Mr. Wedgwood's chief fireman, by whom was made the beads supplied from Etruria during his lifetime (one of which has been heated to 120° of that scale, and reduced to one half of its former bulk, though it has lost only two grains in weight, and one-third of its specific heat); but as he most determinately refused to communicate to Mr. Wedgwood himself the full particulars of their composition, all those sold after his death, which had not been prepared prior thereto, were discovered by different persons, Sir James Hall, Dr. Kennedy, Guyton, Morveau, and others, to want the accuracy possessed

by the others. This is the real cause why pyrometers are no longer sold at Etruria. The statement of Parkes, that clay for the supply of these beads for an indefinite term had been prepared by Mr. Wedgwood, is entirely a gratuitous assertion. Whatever was the modicum of chemical knowledge possessed by him, the practical proofs every day before him, of the chemical reaction of the reciprocal components of his clays, would convince him that any such procedure would be an abortive attempt for the purpose.

Persons who have imitated the beads have obtained results differing not only from those Mr. W. assigned, but likewise from each other. The pyrometer beads he sold, formed of pure alumine mixed with china clay, as well as those made of the latter only, which he had in the first instance supplied to friends for their trials and remarks, differ from his own, in indicating the temperature needful to fuse silver as 22° on the pyrometer gage, not 28° as marked on the scale. He has acknowledged that "he has often found *differences*, astonishing when considered as a part of this scale, in the heats of his own kilns and ovens, without being perceivable by the workmen at the time, or till the ware was taken out of the kiln." The difficulty of compounding a clay which contracts equally by heat has long been considered an almost insurmountable obstacle to the employment of this pyrometer. Mr. Sivewright proposes the substitution of small pieces of the mineral agalmatolite, or Chinese figure-stone, for the beads, because of its regular and equable contraction.

Convinced as I am of the utility and importance of an accurate physical measure for those very high

degrees of temperature, and the absolute necessity for this pyrometer to be based on some other principle than the mentioned property of the natural aluminous compounds; also believing that by a philosophical attention to the principle, and not merely the mechanical agency of the heat, Mr. Wedgwood might happily have succeeded in the attempt, some of its imperfections I have mentioned, from a desire that every means likely to promote its perfection should be adopted. The contraction of clay is dependent as much on the manner in which, as the degree to which, the temperature is raised. The beads are contracted by this last as much in three minutes as they can be in three hours of the same degree of temperature, and the higher this is the more readily is the contraction effected, as far as observation goes.

Manufacturers certainly may derive one advantage from using this pyrometer. Calcined alumine, also aluminous compounds, do not undergo any diminution of bulk by a subsequent application of the like temperature as by any addition thereto. Hence, by adapting to this gauge a fragment of any wares made by other nations, or at other and distant periods of time, and to a raised temperature subjecting it, in company with a proper bead, till the diminution of this commences, there will be supplied correct data of the temperature at which such ware was baked.

Mr. W. Daniell's pyrometer is a tube of black lead, or of flint ware, with a platinum bar. Long prior to knowing this, I suggested to different friends, manufacturers, one constructed in the following manner: The composition of which seggars are formed remains refractory in the highest temperature

of the ovens. Of this composition, by the squeezing-box form a tube, 16 inches long, and 1 inch bore; therein place four bits of the clay, formed with a thin edge, as supports, and firmly close up one end. By the drawing-rod place this tube in any part of the oven where it can rest supported between seggars. Into this tube insert a platinum wire of one-sixteenth of an inch thick, and of suitable length (perhaps twenty-four inches), with one end pressed against the bottom by the slight resistance of the long arm of a compound lever, so combined with others that the smaller end of the last of the series can move the index, which should traverse an arc of six inches, graduated from 62 to 160°. As this bar could be introduced at any period of the baking process, immediately on being raised to the temperature of that part of the oven in which was placed the tube, not only would the degree be always truly indicated, but also the time during which it continued at a certain degree.

The pyrometer invented by M. Achard, of Berlin, appears to me to be capable of such modification as to supply the potter's firemen with a standard for comparing, under any and every condition, the varied degrees of the baking processes. The principle is *expansion* and *contraction* of metals, and when these are constant and uniform, they supply data for relative measures of high temperature, which may be with great advantage adopted by the Manufacturers.

Of hard felspar porcelain body, by the squeezing-box draw out a true half-inch tube, eight inches long; through this pass a true rule, on which form the tube into an oval; to this tube carefully fix a

ball of uniform thickness, and two inches diameter. Bake this ball and stem in the highest temperature of the oven. Purify some bismuth, lead, and tin, and of each respectively take 50, 20, and 30 parts, which will fuse together, and afterwards be constantly fluid at the temperature of 212° Fahrenheit, and solid at 62°. On the stem or tube mark zero 0°; then immerse in boiling water, and pour in the fluid amalgam precisely up to zero. Cool down the whole to 62° Fahrenheit, and the place, as seen through the semi-translucent tube, correctly mark. The interval equals 150°, which divide into *three*, and this will supply the degrees for all above zero, each of which will be equal to 50° Fahrenheit, and may be subdivided into 5 parts. In this must play a porcelain vernier, with a platinum stem, which, as well as the tube, will clearly indicate the degrees of heat. The present trial-holes will need only a little variation of form to admit the introduction of this pyrometer into the oven at different periods of the baking process.

Agreeably to this method of calculation the following table supplies the number of degrees of temperature proper for baking the wares, or melting the metals mentioned. Though sufficiently accurate for ordinary purposes, yet like all other philosophical speculations they must be received with caution, as there cannot possibly be precluded discrepancies in the results of different experimenters :—

	Fahrenheit.	Biscuit.	Glaze.	Wedgwood.
Best Felspar Porcelain - - -	22165	423+	403	156
Champion's Ditto - - - -	19214	368+	356	135
Old Bow Ditto - - - - -	16007	336–	320	121
Common Canton Ditto - - -	15950	329+	320	120
Derby Ditto - - - - - -	15637	308+	300	112
Chelsea Ditto - - - - - -	14727	290+	280	105
Chemical Utensils Ditto - -	14727	290	—	—
Stone Ware Ditto - - - -	14337	282+	270	102
First Worcester Ditto - - -	13297	262	280	94
Bone Earth Ditto - - - -	12583	250	235	90
Flint Earthenware - - - -	12257	244	230	86
Wedgwood's Queen's Ware -	12000	240	230	86
Delft Ditto - - - - - - -	6277	—	—	40
Enamel Colours - - - - -	1857	38	—	6
Gold, for burnishing - - -	1750	35	—	6
	5237	—	—	32
Cobalt - - - - - - - - -	17977	—	—	130
Manganese - - - - - - -	21877	—	—	160
Chrome - - - - - - - -	20577	—	—	150

Great misconception prevails, even among well-informed persons, respecting the degrees of temperature quoted in foreign journals as compared with those of our own, or Fahrenheit's, used also wherever the English language prevails, while Réaumur's is current in Germany, Celsius's (or the Centigrade) in France, and Delisle's is now employed by many philosophical chemists, the interval between the freezing and boiling points being divided by them into 80, 100, and 150 F.

To render the degrees in the above table into equivalent degrees of any other thermometer, any person who knows addition, subtraction, and division needs only recollect that 1 F = $\frac{4}{9}$ R, and $\frac{5}{9}$ C; and 6 F = ·5 D; and 130 F = 1 W. Or, *centigrade into Fahrenheit*, multiply the number of degrees of the centigrade by 9, and divide the product by 5. When the centigrade degrees are below the freezing point, subtract the quotient from 32, and when above that point, add it to 32; the sum will be the equivalent degrees on Fahrenheit. Suppose the centigrade, or French thermometer, at 15 degrees below freezing, multiply 15 by 9, divide the product by 5, and the quotient will be 27, which, subtracted from 32, leaves 5—the equivalent number of degrees on Fahrenheit; and suppose the centigrade marks 20 above freezing, multiply 20 by 9, divide the product by 5, which gives the quotient 35, and, adding 32, the sum will be 67—the equivalent degree in Fahrenheit to 20

in the centigrade. To convert *Réaumur* into *Fahrenheit* multiply the given number of degrees of Réaumur by 9, and divide by 4, and add 32, or subtract the quotient from it, as in the foregoing example.

Connected with this and the following subjects is the problem, *What quantity of atmospheric air is needed to completely appropriate all the heat from the fuel?* The requisite proportion of air must be adequately supplied to the several particles of fuel adapted for fixing and combining with the oxygen of the air. Experiment proves the need of more air than what contains the precise quantity of oxygen for full combustion of the fuel. M. Clement's analysis of the gas discharged at the top of a chimney, where no smoke whatever was visible, and of course the combustion was complete, proved that about two-thirds of the oxygen was not fixed. By Montgolfier's suggestions for determining the effects, proportionate dimensions, and convenient arrangements of parts, of furnaces, to be most useful, M. Clement demonstrates that practice requires thrice the quantity of air to be in contact with the fuel, of what theory would assign for full combustion. For 1 lb. coal, and wood, 20 lbs. and 10 lbs. respectively are required of air. As each cubic foot of air weighs 1·2054 ounces avoirdupois, 527·368 grains troy, a pound measures 13·271 cubic feet. Hence we can determine the quantity of air which in a given time passes through a furnace to consume a given quantity of fuel. Air is 78 nitrogen + 22 oxygen; and to supply heat to dissolve 9·638 ice the combustion of charcoal requires 251 oxygen. The quantity for the combustion of other fuels is estimated by the quantity of ice their heat will melt, assuming that the heat evolved is proportionate to the oxygen required for the complete combustion; and this, for 100 wood, and 100 coal, requires 83, and 166 of oxygen.

COAL.

This abundant combustible mineral, so very important and indispensable an article of the economy of social life in a country devoid of forests, as is Great Britain, is here found in greater plenty than in any other country of the earth. Indeed, could we not thus supply the great demand for this medium of fuel to fix oxygen and concentrate heat in our homes and Manufactories, the country would comparatively be uninhabitable. To the supposition of its being used by the Britons, much probability attaches ; and this is not a little supported by the arrangement of the potter's oven, described in another place ; while of its employment by the Saxons there are numerous proofs.

The prevalent opinions of the philosophic world, founded on the fact that the strata of Coal consist essentially of carbonaceous matter—in the *blind* coal nearly pure—are that the Coal Seams are series of ancient forests overthrown by unknown causes ; or thick beds of very luxuriant vegetation of other kinds of the family, covered and buried by marine debris and deposits, then submerged by irruptions of the sea, and charred by the heat evolved from pressure during countless ages. And, because rocks were not adapted for the growth of forests, whose accumulations and falling produced beds of Coal, mountainous districts do not present us with deposits of Coal suitable for the purposes of the kitchen and the manufactory.

The *Independent Coal Formation*, or the series of Coal Strata, thus designated because the beds and patches and fields are without any apparent connection with each other, is found most plentiful in the floetz, or new secondary rocks, and in the upper series or newest floetz. The strata have the old red sandstone for a general basement, and they alternate with beds of white, red, or grey sandstone, slate-clay, fire-clay, common clay, limestone, ironstone and greenstone. Their direction, unlike that of the primary and secondary rocks, is generally almost horizontal, the inclination, or *dip*, varying from one to six in twenty-four feet, or from three to twelve degrees. Each stratum preserves its own parallelism, and some strata present their natural wavy arrangement undisturbed, but others appear as having experienced some alteration since their deposition. They are not continuous, but, horizontally, and perpendicularly, and obliquely, they frequently are interrupted by *dykes or chasms, slips, hitches, troubles, and faults* (caused seemingly by the strata drying, or the sinking of the rocks beneath, or their being raised upwards, by some galvanic agency), all of which are filled with clay, sand, and rounded stones, carried into them by water, or by rocks of other formations forced into the interstices.

The coal formation consists of many far and wide-extending alternations of sandstone, slate-clay, and coal; often also with beds of ironstone, hydrous carbonate of iron and with modules of iron ore, but seldom with limestone, greenstone, or basalt. The vegetable petrifactions are mostly cryptogamous, few monocotyledons and no dicotyledon, which,

therefore, did not exist when the layer was formed; three species are referred to palms, one to cannæ, one hundred and thirty to ferns, surpassing in size any now known, all of the genera occurring in the torrid zone, without one resembling any recent European species; fourteen to calamites (but whose structure Brogniart refers to equisetums), with gigantic stems, as large as trees, and none such now exist in vegetation; also, of the torrid zone productions are seven species of marsileaceæ, and sixty-eight of lycopodiaceæ. The animal petrifactions are orthoceratites, terebratula, ammonites, and some species of the genera lingula and miro. Some of the mussel-shells occur quite uninjured, but they differ from every known existing species. For the formation of this layer, containing these remarkable vestiges of vegetables and fossils, regular deposits of superincumbent layers would be adequate, without supposing that there has been a change of the inclination of the earth's axis prior to man being formed to inhabit this planet. And electro-chemical action on the vegetable mass may have given it the appearance we now witness.

Britain has such a general distribution of Coals that I need not enumerate all the localities. The districts most likely to supply the fossil are those favourable to forest growth, the valleys over the red sandstone, or over the transition formation, covered with the debris of tides, as clay, gravel, shingle, shiver, etc., occasionally with shells of various species. In these districts attention to the conditions of the bassetings, or out-crops of the strata, will distinguish, almost equally with boring, the nature, quality,

thickness, dip, of each stratum. Also, attention to the water, as astringent and unctuous, or chalybeate and depositing ochre, from having permeated the strata of ironstone and coal—usually in company—and acquired these characteristics, with also a darker tinge.

The extensive Coal Districts of England are from 20 to 120 miles in breadth, and 300 in length, from the Tay to the Severn below Bristol. They are largest in the West Riding of Yorkshire, from north of Leeds and Birstall, to Retford, Nottingham, and Derby; next, of almost equal superficies, in Durham and Northumberland, from Standrop to Berwick, and from Brampton to Belford, according to one calculation, 243 square miles, but another makes it 594; from South Shields to Castle Eden, 21 miles, and 32 west, to West Auckland; thence to Eltringham 33, and to Shields 32. In this district, at Killingworth, is the deepest mine at present worked—the botton is 460 yards perpendicular below the surface. The South Wales Field is from Pontipool to Kidwelly, and from Langhorne to near St. David's. That of Lancashire is from Colne to Prescot, and all the range round Manchester, taking Bolton, Worsley, Clifton, Moston, Chatterton, and Oldham. That of Staffordshire is from Lawton to Cheadle, and from Wolverhampton to Dudley. There are also patches in the counties of Cumberland, Flint, Gloucester, Monmouth, Salop, Somerset and Warwick.

The lowest stratum or bed of Coal in Yorkshire, that from Halifax to Sheffield, lies above the millstone grit, and the series between the grit and flag-

stone is from 120 to 150 yards. This bed is the only one which supplies palpable proofs of successive irruptions of the sea, in regular strata and alternations of land and marine remains. There are present plants and fresh-water shells, also marine shells of the genera pecten, ammonite, orthoceratite, ostrea, and scaly fish, while above and below the pectens are mussel bands. The bed above the secondary limestone is bitumenised timber, with leaves, branches of shrubs, and shells lying upon it, and shells in the intervening shale. In the Newcastle Field the bed 2 yards thick is 150 yards from the surface; and between this and the surface are eight other beds of 5 feet in the whole, the thickest being 1 foot. At 33 yards lower than that first mentioned is another 1 yard thick; 50 yards lower, one of 39 inches; 9 yards lower, one of 38 inches; and 11 yards lower, one of 2 yards thickness—sixteen beds, equal to 11 yards of coal, in 270 yards of ground. The Beaumont seam is 34 inches thick, at 213 fathoms from the surface. In others from 150 to 185. Some portions present 35 feet in 420 yards, 29 feet in 260 yards, and 28 feet in 156 yards. In the South Staffordshire Field are 13 beds, in thickness 23 yards of 120. The first occurs at 16 yards, 10 feet thick; and below are 3 others of 30 feet, with only a few inches of coarse cannel as a separator. The lowest bed, at 115 yards, is near 8 feet thick. Other places show beds at the depth of 1000 yards, and Scotland presents 24 beds in 233 yards. In all instances the intervening strata, from 4 feet to 120 feet in thickness, present us with

sandstone and slate clay; occasionally with shells, but always with animal and vegetable remains.

Now, when we regard Coal Beds as decayed forests, which grew 1000 yards below the present level of the surface, we must suppose an enlargement of the globe, to that extent, at least, to have happened; and for the 16 or 24 successive strata of forests, to have been submerged by the sea in a like manner, we must suppose an equal number of revolutions of the earth's perihelion calculated to occur once in 20·900 years. The period of this Coal formation, according to this hypothesis, would imply an age of our planet of $24 \times 20{\cdot}900 = 501{,}600$ years.

Coal is a compound of charcoal, the soft inflammable substance called bitumen, and a small portion of some earth, unconsumable by complete incineration. The different proportions of these distinguish the species of each kind in reference to inflammability. The hydrogen being from 3 to 30 per cent., as proved by the kinds mined in the counties north of the Trent, and those of Wales, Kilkenny, and Devon; the former burning vividly, with much flame, the latter only with others, or in heated masses. When ignited some varieties become almost as soft as tar; and others cake, or allow the separation of the bituminous and carbonaceous parts, very obvious in a common fire; the coal swells, softens, exhales a kind of bitumen, and burns vividly with smoke and much flame; afterwards these appearances cease, and it burns with a bright incandescence.

Coal is soft, frangible, causing considerable waste in the mining, the fragments rectangular, and almost cubical; the specific gravity 1·265; the colour is velvet black, with a slight intermixture of grey; the lustre sometimes resinous, or splendent, or shining; surface smooth; principal fracture straight, slaty, the plates splendent, or shining only; in caking coal the lustre is shining, and in some of the others occasionally the appearances resemble those of caking coal, but in others specular, or even; and easily distinguished by defective softening and caking during combustion; the cross-fracture usually flat, conchoidal, and specular splendent; and in some, occasional portions with the aspect of wood charcoal.

The three particular kinds of Coal are supposed to be the products of different trees, or of different ages of the world; the *Black, inflammable,* seldom presenting any traces of unaltered vegetable principles, and devoid of the ligneous structure, and the earthy particles, obviously essential to the Brown, and found in the counties north of the Trent; the *Black, uninflammable,* the stone coal of Wales and Kilkenny; and the *Brown,* or Bovey Coal, already alluded to, and evidently wood partially charred, and with only little bitumen present. The former kinds seem composed wholly of bitumen and charcoal, in various proportions, having the mean, per cent., of carbon 74·5, hydrogen 12·5, nitrogen 10·0, oxygen 3·0, contaminated with from 1·5 to 10 per cent. of earthy matter. The species with much bitumen present we find very inflammable, and while in combustion much heat and a bright flame

are supplied; while the species with less bitumen and more carbon will supply heat with a less vivid flame.* Their mining is not by any means a matter of certain or great profit. There are great expenses, of sinking the shaft to *win* them, of constructing paths and railways to the pit, of steam-engines to draw up the coal, and pump out the water, and yet the results are precarious. However, when they are once in this train, the existence of the seam, also its direction and extent, in reference to any other place in the vicinity, may be determined with tolerable accuracy, by observing the dip and cropping out of the strata in the workings.

Components of Coals :—

	Caking.		Splint.		Cherry.	
	Atoms.		Atoms.		Atoms.	
Carbon	33	= 24·75	28	= 21	34	= 25·4
Hydrogen	11	= 1·375	14	= 1·75	34	= 4·25
Nitrogen	3	= 5·25	1	= 1·75	2	= 3·5
Oxygen	$1\frac{1}{2}$	= 1·5	$3\frac{1}{2}$	= 3·5	1	= 1
		32·875		28·00		34·15

Annals of Philosophy, vol. xiv., 91, 2, 3.

* The fact is very remarkable, and to some may seem improbable, that the quantity of heat produced in the combustion of a definite weight of coals is increased by mixture in the state of powder with an equal weight of the incombustible substance clay, moistened with water, to admit of being kneaded together, then formed into cakes or lumps around a thin stick, dried well, and kept in a dry place for use. The fuel in this state will supply much more heat, during a longer period, than can be obtained from coal alone in its crude state. The proportions adopted in Wales are, Welsh coal, in powder, 1 part, clay 2 parts, mixed together and with water kneaded into a hard mass; then, formed into *Coal Balls*, they are placed in the front of a fire-grate, where they burn many hours. I first saw them at Carmarthen, at midnight of a November storm, and only after duly considering the fact could I be persuaded of its utility.

The kind distinguished as *Caking* Coal (or *binding, soldering, crozzling*, etc.) is very readily inflamed, and while the temperature is being raised by the fixation of atoms of oxygen, the lumps break asunder into small pieces; in the degree of admitting the air or oxygen to the igneous mass, is the clearness with which it burns; the temperature being raised to a certain height, the separated pieces again cohere, and form a solid mass, which originates its name. Because of this, care is needed to manage it well; but when, in a common fire, it is regularly stirred to admit the ingress of fresh air, much heat is evolved, and it burns with a lively yellow flame. Of course this property varies in the species. One kind is especially useful for furnaces and forges, because it burns slowly, cakes very hard, and affords a strong and long-continued heat. Another scarcely cakes, but burns quickly, and is preferred for heating rooms, because it makes a brilliant and pleasing fire. Fire is red-hot coal or wood; flame is the combustion of carbon and hydrogen where united with oxygen, the particles being scattered red-hot in the atomic excitement from diminution of volume, and the radiation of protrusion is the effect called light. Hence the gas generated from coals supplies so durable and beautiful a flame. When part of the coal is ignited, and the other part not, the latter evolves much smoke, or hydrogen and carbon, which forms soot. The heat always arises from the fixation of atoms of oxygen by excited hydrogen; and parting with their motion at the surface of the combustible, where the hydrogen evolves, during this latter condition they sustain the heat. A red heat without flame indicates the hydrogen, unsolicited by

other volatile matter, combining with the oxygen as quickly as evolved at the surface. Because of this, and the less dispersion and cooling in the surrounding air, coke is hotter than coal, and charcoal hotter than wood.

Splint Coal (or *hard, slaty cannel* coal) is with more difficulty than caking coal ignited, therefore is not so well adapted for a small fire ; but, as when the combustion has proceeded to a certain degree it separates into pieces, and these soon afterwards become one solid mass, it is for many purposes as valuable as caking coal, and in a large quantity it makes a strong and lasting fire.

Cherry Coal, so named from its beautiful red glow when properly in combustion, requires care to ignite it ; but it burns clearly, with much heat, and a clear yellow flame during a considerable time, until the whole of the coal is consumed.

Cannel Coal does not present any visible composition ; its colour is from dark grey to brownish black ; its lustre, by which it is distinguished from pitch coal, and other varieties, is only little, glistening, resinous ; the fracture perfect and large conchoidal in every direction ; in the grate, frequently slaty ; the fragments very irregular, wedge or cubed shaped ; not readily frangible, and does not soil the fingers ; specific gravity 1·272 ; the atoms are carbon 11 = 8·75, hydrogen 22 = 2·75, nitrogen 1 = 1·75. It readily ignites, and supplies a clear yellow flame, but not much heat, without melting, and hence its use in kitchens, during the winter season especially ; there is a crackling noise connected with the ignition, and fragments, very dangerous on every account, only are

prevented flying to different spots in the apartment by dipping the block previously in water, and placing the cross fracture next the fire; the block separates into leaves, which can be placed in any other chosen direction.

Coke is the residue of coal, prepared either in a close vessel, as a gas retort, or in a pile or open kiln; it is denser than charcoal, the similar product of recently cut wood; and the kind prepared in a kiln has powers of heating which greatly surpass those of the coke from gas retorts.

The several kinds of coal differ much in their capacity to fix oxygen and supply heat; yet to this standard of relative value I cannot find that the chief consumers of the fossil have paid proper attention. The investigations in reference to the supply of gas afforded have scarcely the slightest reference to Manufacturers' use of coal. Only by combining the results of heat supplied and the price can we determine the relative value of coals. The problem then is—*What is the supply of heat by each kind of coal?*

To determine this we completely incinerate each kind, and by ascertaining the proportion of charcoal present, and the residuum of earthy ashes per cent., we can correctly determine the proportion of bitumen. This last is indifferent to the presence of nitrate of potash, which detonates, and is decomposed by that of ignited charcoal. The quantity of charcoal needful to decompose a given weight of nitrate of potash indicates the proportion of carbon present, and has been determined as carbon 13·21 to nitrate of potash 100, in close vessels under water, and as carbon 10 to nitrate of potash 96, or plumbago 10 to nitrate of

potash 96, in open vessels in air. The nitrate of potash is put into a very large crucible, which is placed in an air-furnace; the coal is reduced to powder like rape-seed; when the alkali is incandescent, the detonation is kept up by projecting a grain of coal in succession till it wholly ceases. The quantity of coal required must be compared with that of charcoal. Wigan cannel when incinerated gives earthy ashes 3·12 per cent., and 66·5 grains decomposed 480 of nitre, which only needed 50 of charcoal; consequently 66·5 grains of cannel are composed of 50 charcoal, 2·08 earth, and the remaining 14·42 grains must be bitumen. By this process I have obtained the following results of coals in my own neighbourhood: *Kidsgrove*, charcoal 72, earth 6·12, bitumen 21·88; *Biddulph*, charcoal 76, earth 7·09, bitumen 16·91; *Bignall End*, charcoal 72, earth 5·08, bitumen 22·92; *Chesterton*, charcoal 76, earth 8·0, bitumen 16·0; *Apedale*, charcoal 76, earth 7·33, bitumen 16·67; *Silverdale*, charcoal 76, earth 7·5, bitumen 16·5; *Golden Hill*, charcoal 77, earth 8·5, bitumen 14·5; *Tunstall*, charcoal 78, earth 7·5, bitumen 14·5; *Scotia*, charcoal 78, earth 7·0, bitumen 15·0; *Bykers*, charcoal 77, earth 8·6, bitumen 14·4; *Hamill*, charcoal 78, earth 8·5, bitumen 13·5; *Shelton*, charcoal 77, earth 8·4, bitumen 14·6; *Joiner's Square*, charcoal 78, earth 8·7, bitumen 13·3; *Bucknall*, charcoal 77, earth 8·7, bitumen 14·3; *Foley*, charcoal 77, earth 8·25, bitumen 14·75; *Lane End*, charcoal 78, earth 8·4, bitumen 13·6; *Moss Field*, charcoal 72, earth 7·5, bitumen 20·5; *Norton*, charcoal 76, earth 8·5, bitumen 15·5.

The annual consumption is calculated at less than

30 million tons ; on the average of 8 tons for each family in England and Wales, or 20 millions ; and from 6 to 10 for gas-works and the manufacturing processes. The apprehension of a failure in supply is a chimera. For, even did not science bid fair to discover other and briefer means to generate heat, yet on the average of a ton per annum for every inhabitant in the United Kingdom, there is plenty for some thousands of years. Bakewell calculates that South Wales would alone supply all England and the Principality for 2000 years as the present rate of consumption ; and certainly it must be the resource of the metropolis whenever danger or expense prevents the supply from Newcastle. Forster *guesses* that in the Welsh Coal District are 16 thousand millions of tons, diminishing annually at the rate of 3 millions of tons. Its surface is twenty times that of the Tyne district, and its mean thickness is 93 feet ; and that has a mean thickness of only 12 feet, with a superfices of 837 square miles, of which 105 have been mined in 300 years, and therefore the 732 miles left will afford a supply for 2000 years longer. Mr. Taylor, coal agent for the Duke of Northumberland, calculates thus : "Each square mile contains 12,390,000 tons ; then 732 square miles has 9,069,480,000 tons ; deduct, for losses by small coal, dykes, and other interruptions, one-third, or 3,023,160,000, there remain 6,046,320,000 tons, which are adequate to supply the present sales from Newcastle, Sunderland, Hartley, Blyth, and Stockton, of 3,500,000 tons, for a period of 1727 years."

In 1827 an intelligent Spaniard demonstrated that the annual value of the coals raised in Great

Britain greatly exceeds that of the precious metals raised in the New World; likewise, that the value of manual labour in quarrying the coals exceeds that of the valuable metals found in the Transatlantic Continent. Thus, 30 million tons of coal at twelve francs fifty cents per ton give 375 millions of francs; or at twenty-five francs per ton, mean cost 750 millions of francs; and this minus the first cost is 375 millions for the value of the labour. Now (according to Humboldt, *Essays, New Spain*), all the precious metals were 217,500,000 francs, giving a difference in favour of coal of 7½ millions of francs. The cost of carriage to the consumer, coastwise, is forty francs, inland, twenty francs. The cost of silver carried from Potosi to Buenos Ayres, 500 leagues, is 2 per cent. (gold rather more), or about 5 millions of francs for the whole. The value of the coals, payment for labour, and profits, amount to 750 millions of francs, and that of the gold and silver, carriage, etc., 222½ millions of francs; the difference in favour of the English coal trade being equal to 527½ millions of francs.

Steam Heat—*for the Printer's Stoves.*

Wherever steam-heat is introduced, the apparatus must be constantly kept in order by a person deputed especially for that purpose; and in his hands it is perfectly safe, easily managed, and efficiently directed to any distance within 250 yards from the boiler, yet retain the heat of 212° Fahrenheit, and rise above, in proportion to the high pressure secured by the boiler and the pipes.

One single fire will provide steam for a very large establishment; and the steam will ascend, descend, or pass along horizontally with undiminished velocity, and without any abatement of its temperature.

There is a very common assertion, that steam-heat is more economical than that of smoke-flues. How the comparison has been made is not known; but he must be a novice in the science of heat who cannot produce nearly the same effect by the one as by the other, under precisely similar conditions. In either method it is easy to mismanage things in such a manner that no more than half the heat will be effective in warming the intended space; and by selecting cases for comparison, you may make either appear the best method, as far as regards economy of heat. Where a proper attention can be given steam is preferable, but in other cases flues will be found to answer better.—*Tredgold.*

PRINTING.

In 1832 I suggested to Mr. H. Davenport the employment of a series of strong gas-pipes, inch bore, arranged like a gridiron or the generator of some steam-carriages, and to be hermetically sealed after being filled with hot water, or with a small wooden peg at one extremity, if supplied with steam. Now if a part of this series be placed near a fire, or in the flue of a fire-brick furnace, and surrounded with ignited coke, the heat of the water may be raised to any required temperature, and continued *ad libitum.* The heat by the water appropriated from the fuel is equal and constant, and can be reduced or increased by merely opening the flue doors or stoking the fuel. The water will be circulated equally, whether the gridiron is above or below the level of the fire-place, and at a temperature of 300° to 600°.

Now Perkins and Bacon print bank-notes from an arrangement of this kind; and we only need to get rid of the prejudices in favour of open stoves to get rid of dirt and other inconveniences. At 400° the pipes will roast meat; and at any part of the arrangement a beef-steak will be readily dressed.—(*Gardener's Magazine,* 38, for a kind of apparatus.)

CHAPTER III.

ACIDS AND ALKALIES.

Acid and Alkali are generic correlative names for two antagonist classes of substances the reverse of each other. In the former the oxygen of the atmosphere, mostly, is the active element, whether by combinations abstracted or by positive electricity; in the latter the nitrogen of the atmosphere is the active element, inverse in potency to the other, and as concentrated in negative electricity, and an important feature in nature results from their reciprocal actions and reactions. Their peculiar properties and potencies as recipient and agent in one kind of combination with each other, in strict accordance with their respective combinatory proportions, render inert, neutralise, or saturate each other's active potency, so that the equal and reciprocal action and reaction preclude the appearance of any aciduline or alkaline phenomena, because the components in those respective proportions are reciprocally saturated, and form certain crystallisable compounds, saline substances, or salts.

There will appear, *en passant*, numerous instances of the probability that the method of

combination—more than the properties—of the components will cause the result to be acid or alkali. The two, more clearly than any other scientific arrangement, elucidate the doctrine of *Cause and Effect*, as mutually and reciprocally dependent, and subject to the law under which the Creator's fiat first gave them existence. By the word *alkali* primarily was signified merely the caustic result of evaporating the water in which had been washed certain incine rated plants.

The alchemy of Davy on the alkaline oxides first exhibited how the intense atomic motions concentrated by the galvanic circuit could so assist the oxygen and nitrogen of the body and the air that the medium might permit the metal to present us with the phenomenon of a pure alkali, and that on changing the medium union with oxygen fits it for again enduring the atmosphere, as potash. In the pure potash the oxygen and nitrogen were disturbed, the oxygen was dispersed, and the reaction of the nitrogen placed the metal, as pure alkali, at the negative pole. Indeed, careful consideration of the phenomena demonstrates that they all are a mechanical restoration of a disturbance of the oxygen, hydrogen, or nitrogen, or their correlative motion, the peculiar potency of each, through certain recipients, which by being the medium of precise equivalents of positive and negative, may be in condition altered, partially or wholly.

Acidity and *Alkalinity*, in some of their conditions, seem to be Nature's active principles, whose effects are measured by the relations of two certain atomic motions. Positive and negative electricities

may be regarded as pure oxygen or acidity, and pure hydrogen or nitrogen, or alkalinity. Hence the peculiar potencies of their contrast and action, completely distinct from those of either when operating alone.

We need a certain guide to illustrate the truly mysterious subject—what difference in atoms renders them aciduline or alkaline, and neutral. We know that only when *in motion* gas or fluid have atoms as these powers, of which they are destitute *when fixed.* Now, gas being the result of atoms moving in circular or orbital directions—can this be the true or real cause?—the varied inclinations of the planes of the orbits to surfaces in reference to each other, the acid atoms may operate vertically, the alkali atoms horizontally, and the diagonal or intermediate angle be the neutral state, the results being governed by bulk, momenta, and combinative potency.

Acids are those peculiar substances which particularly affect others dissimilar, whose reactions cause certain results; thus, with the alkaline, earthy, and metallic oxides, in water as a medium, they form neutral salts. Much the greater number are: 1. Sour to the palate; the plus of oxygen affecting the sense of taste; yet that this is a result of equivalence of acid and alkali seems probable from the fact that it is pleasingly harmonious for the aciduline power to be destroyed by suitable combination with an alkali. 2. They corrode substances; and this well-known effect of the acid on the substance suggests many applications of acids to accomplish a great variety of purposes and changes, in different

departments of the Arts of Life. 3. They are soluble in water to an extent not precisely determined. 4. They change to a red tint the purple and blue juices of vegetables, and to a brown those which were green.

The ALKALIES in all probability have the principle the same, but the medium of its operation causes a real difference in its phenomena. They are of three classes, those in which oxygen is combined with a metallic base—Potash, Soda, Lithia; that without oxygen—Ammonia; and those with oxygen, hydrogen, and carbon—the vegetable alkalies, supposed to be of like number to the vegetable acids. Their potency is determined by the quantity of acid rendered inert; thus, sulphuric acid 7 lbs., at 1·8485 specific gravity, exactly neutralises 10 lbs. of carbonate of potash, 66 of potash, 75 of carbonate of soda, and 44 pure soda. Besides forming salts by neutralising acids, the alkalies, potash, soda, lithia and ammonia, 1. Change vegetable colours, the reds to a purple, many purples to a green, and yellows to a red-brown; the red of an acidulated purple is destroyed, and the purple restored by an alkali. 2. This potency on vegetable tints (like continued solubility) remains after the alkali is saturated with carbonic acid, distinguishing alkalies from alkaline earths, as carbonates inefficient. 3. Applied to the palate the savour is urinous and acrid, caustic to the tongue and skin. 4. They forcefully, as solvents or corrosives, combine with organic compounds or animal substances, and with animal fat and vegetable oils they form neutral soap. 5. They combine

with water in every proportion, and almost so with alcohol. 6. At bright incandescence they decompose and are volatilised.

The neutralised atmospheric air in which substances exist by weight is composed of oxygen 1 and nitrogen 3·5, to which standard there seems indispensable necessity for these substances to be accommodated. With each of the *aciduline* bases oxygen is present to such a degree of equivalence for neutralisation that any additional proportion above those needful to produce its stable condition and ensure its sustentation of the atmosphere renders the substance an acid ; as the gas by hydrogen (supposed by some persons to be constantly a component of), nitrogen, the intractable carbon, refractory silicum, boron, the volatile substances sulphur, phosphorus, selenium, arsenic, antimony and tellurium ; and chromium, with the six new laboratory productions, vanadium, molybdenum, tungsten, tantalum, titanium and osmium. With each of the *alkaline* bases nitrogen is present with such equivalence that in the ordinary state of the atmosphere an additional dose of oxygen causes neutralisation, and the result is an oxide or earth in which acidity is not perceptible (as those from which the galvanic circuit exploded or protruded the oxygen, potassium, sodium, lithium, barium, strontium, calcium, and magnesium ; also the six others, which, oxidated, form white earths, aluminum, glucinum, yttrium, zirconium, thorium, cerium). Acids solely oxidate iron, nickel, cobalt and manganese. The other fourteen metals preserve the metallic state, yet are by heat or combustion

oxidated in various degrees. All of these bases having present in their metalline state more alkali than the atmosphere, or neutral proportion of 3·5 to 1, the addition of small proportions of oxygen form oxides, without acidity. We may regard carbon as neutral, yet by additional oxygen converted into carbonic acid; and potassium as an alkali, by oxygen reduced to the standard of 3·5 to 1 in potash. Gay Lussac regards the alkalinity of metallic oxides as resulting from the two distinct sources—the alkaline nature of the metal, and the acidity of the oxygen, under modified proportions and combinative potency.

To form the fixed alkali an additional dose of oxygen is necessary to balance that in the atmosphere, and capacitate the alkali to exist without further neutralisation. Suppose the base a compound of nitrogen and carbon, or silica (as, if potassium were nitrogen 2, carbon 2, or silica 2; *i.e.*, $2 \times 3{\cdot}5 = 7 + 2 \times 3 = 6 = 13$, or $2 \times 3{\cdot}5 = 7 + 2 \times 8 = 16 = 23$; also, if barium, a more potent alkali, were nitrogen 4, carbon 2, or nitrogen 4, silica 2; *i.e.*, $4 \times 3{\cdot}5 = 14 + 6 = 20$; or $14 + 16 = 30$; to which, if hydrogen be not constantly a component of nitrogen, one must be added for the metal's combustion and fixation of oxygen), then the conversion of the metal into an alkali is the addition of one proportion of oxygen, and the conversion of the alkali into metal is the abstraction of the oxygen, and the substitution for it of one proportion of hydrogen, as the means of its combustibility as a metal.

Of real *Acid*, in this succession, Sulphuric, Nitric, Muriatic, and Carbonic, the Alkalies and Earths 100 parts appropriate: Potash 82·48, 84·96, 56·30, 105·00; Soda 127·68, 135·71, 73·41, 66·80; Lithia, with each variable; Ammonia 383·80, 247·82, 171·00, and variable; Barytes 50·, 56·, 31·80, 28·2; Strontia 72·41, 85·56, 46·, 43·20; Lime 143·, 179·50, 84·49, 81·81; Magnesia 172·64, 210, 111·35, 200; Alumine 150·90, variable with both, 335·00.

The above acids above 100 parts appropriate of the Alkalies and Earths in this succession: Potash, Soda, Lithia, Ammonia, Barytes, Strontia, Lime, Magnesia, Alumine; Sulphuric 121·48, 78·32, 67·90, 26·05, 200·, 138·, 70·, 57·92, 65; Nitric 117·70, 73·03, 65·48, 40·35, 178·12, 116·86, 55·70, 47·64, 53·80; Muriatic 177·60, 136·20, 128·74, 58·48, 314·46, 216·21, 118·30, 898· 947·30; Carbonic 95·10, 149·60, 118·36, variable, 354·50, 231·, 122·, 50, 64.

The Combinative Tendencies, active and receptive of Acids, Alkalies, and Earths:—

	Sulphuric.	Nitric.	Muriatic.	Acetic.	Carbonic.
Potash	62	58	32	26	9
Soda	58	50	28	25	8
Lithia	56	48	26	23	7
Ammonia	46	38	14	20	4
Barytes	65	62	36	29	14
Strontia	62	60	34	28	13
Lime	54	44	20	19	12
Magnesia	50	40	16	17	6
Alumine	40	36	10	15	2

BORACIC ACID.

This rare production of the mineral kingdom is in silvery white, thin, irregular, hexagonal scales, brittle between the teeth, but not ductile, specific gravity 1·479, to the touch greasy like spermaceti, savour first sour, next bitter and cool, afterwards pleasantly sweet, odour none till treated with sulphuric acid, when one like musk evolves, almost insoluble in water at 212°, but soluble in alcohol, and the solution burns with a beautiful green flame; not affected by the solar rays; it effervesces with alkaline carbonates; vegetable blues it renders red, yet it gives this tint to turmeric also. It has been recently discovered, to the quantity of 9 per cent., free, in several lakes of thermal waters near Monte Rotondo, Berchiais, and Castello Nuovo, in Tuscany, also in large quantities in a solid state; and it has been so reduced in price thereby as to allow of its use to combine with soda, and form Borate of Soda, or Borax. Its crystals are acid 57 + 43 water, in two proportions, one for crystallisation, the other as a base to the acid.

The honour of discovering *boron*, the base of boracic acid, is divided among Davy, Gay Lussac, and Thénard. The first, on subjecting it to the potency of the galvanic circuit, obtained a small portion of a chocolate-coloured substance, solid, without savour or odour, specific gravity 1·025, and atomic weight 1. The others mixed boracic acid with an equal quantity of potassium, and at a low red heat obtained *boron* and sub-borate of potash.

Process.—For a small experiment a glass tube will answer, but on a larger scale one of copper is preferable: Well dry both the components, potassium and boracic acid; then intimately mix them, put the mixture into the tube, loosely cork up the ends, and expose the whole to the fire till incandescent; then withdraw the tube, and when cool, with hot pure water wash out the whole of the calc, and let the liquid repose twenty-four hours; filter the decanted liquid, wash the filter till the washings are not affected by syrup of violets. The boron dry in a capsule, and put into a phial, which keep well closed.

When the temperature is very gradually raised the water of crystallisation is dissipated, and the boracic acid melts a short time previous to incandescence, which state it attains, and loses half its remaining proportion of water, and then fuses freely into a glass with specific gravity 1·803, permanent in the highest heat of the potter's oven, where the remainder of the water is dissipated; hence its great utility as a component of the best glazes. This glass, after exposure to the atmosphere, is a shade opaque, without soliciting moisture from it; yet its properties continue, for after being dissolved in boiling water it can be recrystallised for use in the artificial gems or pastes. But when the rise of temperature is great and sudden, because the water of crystallisation cannot gradually evolve, the assay intumesces or bubbles up, and the acid sublimes and is called *calcined* Boracic Acid. Because of this peculiarity, and when other components of the glaze cause a sudden rise, there are occasional defects in the glazes. When mixed with soot at a high temperature is formed a pitchy compound, soluble in water but subliming by calcination, and scarcely is

the acid, mixed with fine charcoal powder, vitrefiable by a high temperature.

Boracic Acid with greater momentum solicits Lime to combination than it manifests towards any other base; yet it sluggishly forms BORATE OF LIME by mixing its solution with lime-water, or by lime-water separating the soluble alkaline borates. In each borate of lime precipitates, insipid, white, and scarcely soluble in water. BORATES OF BARYTES and MAGNESIA, except being insoluble, are in other respects similar. In a direct way *Borate of Alumine* is with difficulty formed. At a very high temperature boracic acid combines with silica, and forms the solid vitreous permanent *Borate of Silica*, insipid, insoluble, changeless by the atmosphere; and with the momenta of accelerated atomic motions at high temperatures soliciting to combination borates previously saturated with other bases. Hence also the beautiful transparency of glazes in which this predominates. The *Borate of Potash* has been seldom employed, either in its neutral state or with excess of base; yet in the Arts it is as useful as the next article.

BORATE OF SODA, BORAX. This compound, found native in different parts of the East Indies and South America, has long been an article of commerce, as *Tincal*, and considerable quantities are consumed weekly for glazes, although considerable risk attaches because of its impure state and varying alkalinity. During a considerable period the method of purifying Tincal into Borax was known and practised by only the Dutch and Venetians, but

the processes have been ascertained, published and improved. M. Chaptal's process is operose yet very useful. He carefully boils during a given time [16 hours] a solution of tincal, which after being filtered is evaporated, left to crystallise, and the resulting crystals are subjected to a like process. The crystals obtained by the latter are white and transparent hexagonal prisms surmounted with pyramids; the savour is styptic, and the fracture greasy. It is soluble in 6 parts of water, at 212°; and when this solution is distilled in a retort, part of the boracic acid rises during the process and crystallises in the receiver (an excellent form for the pure *test*). It is very soluble in alcohol, also in alcohol and water, for paper dipped into a mixture of the latter burns with a green flame. By raised temperature borax intumesces, boils, loses its water of crystallisation, and fuses into a white opaque porous powder, called *Calcined Borax*, and a higher temperature renders it a yellow, transparent, efflorescent *Glass of Borax*.

Process.—A new Borax. In pure water, at 212° Fahrenheit, dissolve common borax till the specific gravity is 1·246, then lower the temperature. At 174° crystals begin to form, and continue forming till the temperature is at 133°; then decant the liquid. With the same definite proportions of acid and base, and only half of the water in common borax present, the specific gravity is 1·815 (common borax 1·74) It is not brittle by the sudden application of 30 or 40 degrees of raised temperature, but it is harder, swells less, flows easier, and therefore probably is more useful than common borax.

Analysis of Borax.—Of the sample brought weigh 78 grains; also, of sulphuric acid (specific

gravity 1·800, or 70 per cent. real acid) 14 grains; this acid carefully add to the salt, and the solution will acquire the tint of onion-peel (not a wine-red), and the shade of the tint will instantly show the quantity employed, subtracting the last grain; and when the whole of the acid is needed, the article is genuine (supposing only soda and boracic acid present).

Boracic acid has been observed in the craters of certain volcanoes, particularly in that of Vulcano, one of the Lipari Islands; it was first observed as a deposit from the thermal springs of Sasso, in Sienna, Italy. It exists also in plenty in the Lagoni, in Tuscany.

Considerable quantities are imported to be converted into borax for the potter's use in glazes.

The kind of Vulcano is in small scales, translucent, having a pearly lustre and a white colour, except when tinged yellow by accidental presence of sulphur.

It is very light, and the scales adhere to the fingers; slightly saline savour, soluble in water, by which is separable all sulphur, from 5 to 20 per cent. At first it tinges green the flame of a candle, until the water of crystallisation is completely dissipated, when that tinge disappears. Stromeyer regards it as then pure, but with its water of crystallisation.

MURIATIC ACID.

MURIATIC (or Hydrochloric) ACID, the spirit of salt of former times, is sour in savour, pungent and peculiar in odour (which so irritates the epiglottis as to prevent its entry, else death would ensue), corrosive to the palate and tongue, with a specific gravity 1·384. Raised temperature changes its bulk, not its properties.

Process.—Take a tubulated glass retort, and to the beak lute a long glass tube, with the free end recurved to dip into the mercury of a pneumatic trough. Into the retort put 8 parts of decrepitated sea-salt; into the tube put chloride of calcium (or ignited muriate of lime), and let the bent end dip into mercury, when convenient. In the tubulure fix a syphon-funnel ground close, and through this introduce at intervals 5 parts of concentrated sulphuric acid. The gas which evolves in contact with air forms a hazy cloud, with beautiful prismatic tints in a strong light, but invisible, yet having all the mechanical properties of air, in a glass jar over mercury. This gas is muriatic acid—a compound of chlorine and nitrogen.

The muriatic acid of commerce is gas 3, water 6, and is thus prepared :—

Process.—A tubulated retort of glass or of iron with a pottery head and a well-ground stopper is connected with a receiver containing a certain quantity of pure water. Into the retort put a mixture of decrepitated salt 44 parts, and pure water 19 parts, then mix sulphuric acid 28 and water 9, which add to the mixture in the retort, and immediately close the tubulure. Without artificially raising the temperature, the sulphuric acid solicits to

combination the alkali, from which the muriatic acid gas evolves and is condensed in the water in the receiver to double its weight, yet with increase of bulk of only one half. This product is muriatic acid, of a straw colour whenever there is impurity in the salt or an accidental spice of iron. The dry residuum is persulphate.

When a burning taper is introduced into chlorine, it is quickly consumed with a dull red flame, which throws off a dense black smoke: phosphorus spontaneously ignites in it, and burns with a pale-white flame, and several of the metals, in a finely-divided state, or in thin leaves, inflame; and in this way tin, copper, and zinc exhibit a beautiful appearance. Chlorine, mixed with the vapour of water, as it is usually obtained, assumes the liquid form at a temperature of 40°; and when surrounded with snow or pounded ice, concretes into a solid of a yellowish colour, which is deposited upon the sides of the receiver, like the effects of frost upon the surface of windows. If the gas be artificially dried by passing it over substances which abstract vapour, as a salt known by the name of muriate of lime, the most intense artificial cold produces no effect upon it. Strong compression, equal to four atmospheres, will, however, reduce it to the liquid form. It has no acid properties: it is not sour, and it does not change the blue colour of vegetables to red; but it destroys all animal and vegetable colours, and is a most important agent in the art of bleaching. This, however, it can only effect when water is present.

NITRIC ACID.

NITRIC ACID is without colour, has little odour, harsh savour, and corrosive potency on organic substances, rendering yellow those in which nitrogen is present, with specific gravity 1·51, in which concentrated state it abstracts moisture from the atmosphere, and is yellow only when nitrous acid is present. Its components are hydrogen 1, nitrogen 1, oxygen 3, or $0{\cdot}25 + 3{\cdot}5 + 12 = 15{\cdot}75$. Its great utility in the Arts results from the facility with which metals, tin, copper, and mercury in particular, solicit oxygen to combination, and thereby become soluble. When nitric acid 52 parts are mixed with pure water 48 parts, the bulk is only 96·65; and the previous temperature of 60° is raised to 140°; it boils at 248°, and freezes at −50°.

Process.—Retorts of very thick pottery, or cast-iron, with earthen tubulated heads, are properly connected with a range of receivers, in which is pure water, in quantity proportioned to the strength to which the gas must be condensed, by refrigeration with cold water or ice, and all the joints are carefully closed. For the strongest nitric acid, put into the retort very pure nitrate of potash 60 parts and concentrated sulphuric acid 40 parts; instantly stop closely the tubulure with the recurved glass tube. Slowly raise the temperature, during about sixty hours. First there evolves a red fuming vapour, whose tint gradually softens to a pale, or even colourless gas when the nitric is very pure and all the materials clean; afterwards the red and fuming vapours re-appear, and continue till the process is concluded; the whole product has a bright marigold tint, and is in quantity equal to two-thirds the weight of the nitre. The receiver is emptied and replaced, and through a funnel of small bore cautiously is introduced a very fine stream of

pure water 20 parts ; the distillation is resumed, and a weaker acid obtained, which is usually kept separate.

Aqua Fortis, a weaker kind for common purposes, is sometimes sophisticated with sulphuric and muriatic acids, or one of these. When there is reason to suspect the Article supplied by the dealer, test 30 will by a white precipitate detect the former, and test 32 by milkiness the latter acid. To separate these—add each test till the precipitate ceases ; then decant the liquid, and in an apparatus well-fitted together by grinding, and closely secured by Indian-rubber caps over the joints, again distil all of the former, and about $\frac{7}{8}$ths of the latter liquid.

SULPHURIC ACID.

Sulphuric Acid is without colour or odour, but is very sour to the palate, and extremely caustic and corrosive to the skin, with combinative potency on litmus so very great that a single drop will render red an immense quantity of water, through which one drop of litmus tincture has been diffused. Its components are hydrogen 1, sulphur 1, oxygen 2, or $0{\cdot}25 \times 4 \times 8 = 12{\cdot}25$, specific gravity $1{\cdot}845$; so seemingly oily, as to be in common parlance named oil of vitriol; so attractive of water, that when exposed to the air one day it imbibes a third of its weight, and six times its weight in a year. With such Momentum does it combine with water, that a rise of temperature from 60° to 320° is consequent. It boils at 620°, distils without change of properties, and freezes at − 15° It is the result of combustion of sulphur, maintained by oxygen present, in a close vessel to prevent the escape of volatile vapours, with water in which they can be condensed.

A chamber is formed, all of whose sides are lined with lead, and adapted to be readily closed from the atmosphere. A furnace is fixed to supply heat, and the flue passes beneath the floor of the chamber. Near one side, and a foot above the bottom of the chamber, is fixed a strong iron plate over the furnace; this has its outer edges raised as a rim. On this iron plate is placed a small chamber to contain the combustible materials, 8 parts of sulphur and 1 part of nitrate of potash. The bottom of the chamber

is covered with a shallow stratum of pure water, and a small valve in the roof of the chamber is the only aperture for the air. The temperature is gently raised till the materials are ignited, which soon occurs; from the nitre oxygen evolves, the vapours from the sulphur are thereby acidified, and the water is by them solicited to combination. Care is taken always to adapt the quantity of the materials to the oxygen of the air present, and to be supplied by the nitrate of potash. When the combustion ceases, the resulting sulphate of potash is withdrawn, and another supply of sulphur and nitre introduced, adapted to the condition of the chamber. Thus are the products formed and condensed in the water until other combustions do not render it more aciduline, which is when the liquid is about 1·390 specific gravity; it is afterwards drawn of by stop-taps and concentrated by distillation, first in a large pan of lead, and afterwards in a glass retort placed in a sand-bath; or, most economically of fuel and time, in proper-sized alembics of platinum, placed within pots of cast-iron.

Process.—Pure Sulphuric Acid for Analysis. Add to the acid an equal weight of pure water, and leave the whole to repose 24 hours; into a retort carefully annealed previously, and of capacity for four times the quantity of liquid, place a few fragments of cullet, and on this decant the clear liquid. Place the retort over a charcoal fire just ignited, and by a very long adopter connect it with a receiver, refrigerated in a vessel of cold water; gradually and carefully raise the temperature, and the acid will regularly flow over, and must be kept securely stoppered from all foreign matters.

Judicious management obtains 2000 parts of concentrated sulphuric acid from a suitable supply of sulphur to 100 parts of nitrate of potash. After the combustion of the sulphur, the nitrogen having evolved, the potash is become sulphate and bi-sulphate, with little diminution of the 39½ parts of oxygen first present, not one-thirtieth of that now present in the liquid. This causes the inquiry: Whence then are the more than 1000 parts of oxygen obtained? Clement and Desormes and Sir H. Davy have supplied the following theories of their origin :—

During the combustion the sulphurous acid solicits a portion of oxygen from the nitrate of potash, and forms sulphuric acid, whose combination with the potash causes a little nitrous and nitric acids to evolve in vapours which the sulphurous acid decomposes, and the result is deutoxide of nitrogen, or nitrous gas, a little denser than atmospheric air. This gas, by the raised temperature of the chamber, expands, ascends to the roof, and might escape by the valve essential to the supply of air for acidification, but its contact with the oxygen of the atmosphere produces the ponderous aëriform nitrous acid vapour, and every three parts of it is solicited by four parts of the sulphurous acid flame, and sulphuric acid results; then, resuming the form of nitrous gas, again it reascends, solicits a fresh supply of oxygen, is as before precipitated, its oxygen appropriated by the burning sulphur, and thus the alternate metamorphosis of a small quantity of nitrous gas into oxide and acid supplies aciduline potency to the vapours of a large quantity of sulphur.

This excellent theory is modified thus by Davy: Water must be present for deutoxide of nitrogen to convert sulphurous gas into sulphuric acid; and a small proportion of water, 4 parts of sulphurous acid gas, and 3 parts of nitrous gas, condensed into a crystalline solid, instantly separates in much water, and forms oil of vitriol; deutoxide of nitrogen evolves, and becomes nitrous gas by contact with the air. The process continues, according to the same principle of combination and decomposition, till the water is strongly aciduline.

POTASH.

POTASH, in the state of hydrate, is brittle, white, with odour like that perceived when slaking lime, very acrid savour, caustic, and so corrosive as immediately to destroy the animal or vegetable fibre to which it is applied. Like negative electricity it renders of a green tint vegetable blues, and the purple infusions of cabbage and violets, that of turmeric to a bright brown, and the red aciduline infusion of litmus to purple; it dissolves resins, converts fixed oils and fat into soap, and without effervescence neutralises acids. It is the well-known alkali obtained by lixiviation of the ashes from the incineration of vegetables, fumitory, fern, wormwood, potato-tops, etc., cut before the seed time; and being erroneously supposed peculiar to the vegetable kingdom, was named the *Vegetable* alkali (in contradistinction to Soda, which was named the *Mineral* alkali). The ashes are washed in twelve times their weight of boiling water, or till the water is insipid; the solution is carefully decanted into iron shallow vessels and evaporated dry, and the Potash as a dark-coloured salt remains, certainly mixed with some other substances, but in a condition to exhibit many of its characteristics as the *potash* of commerce. Incandescence in a reverberatory furnace separates many of its impurities and forms it into *pearlash*, of limited potency, because of the presence of carbonic acid.

The supply obtained per cent. is, from wormwood 74, fumitory 36, sun-flower stalks 34, Indian

corn stalks 20, vine branches 16, beech, elm, fir, etc., 10 to 12. It is asserted by some writers that were these vegetables grown near the strand, or on soil manured with sea-salt, soda, not potash, would be the resulting alkali, probably by varying the manner in which the nitrogen solicits the others to combination. The early Gauls and Germans formed soap of beech ashes and tallow, and the *konia* of the Greeks was a potash ley.

The hydrate of potash is so well known to have its component principles so loosely combined, as to admit of its being employed as a most delicate test and medium of determining the presence of acid or alkali. When put into a solution of common salt and water, it combines with the muriatic acid, and the soda remains free, but suspended in the liquid.

Process.—In 4 parts of water dissolve one part of pearl-ashes; then on 1 part of fresh-burned lime sprinkle a little cold water, and when it has fallen into a fine powder, diffuse all of it in plenty of water. Mix the two liquids, and in a clean iron kettle keep at 212°, well stirred, about 1 hour, then through a filter of calico pass the fluid into a silver evaporator, and dissipate the water till the residuum will, when cold, be of the consistence of honey. Next put this into a phial, and add alcohol until all is in solution; then raise the temperature to 180°, and stop close for 24 hours, during which the liquid will separate into two portions, the upper being pure potash, dissolved in alcohol. This portion carefully decant into a silver alembic with a glass head, and distil over the spirit (or, decant into a silver basin), and evaporate properly for crystallisation (which will take place though alcohol may be present) on cooling; and then pour into a crucible, by high heat fuse it, pour it on a silver dish, and when at 63° Fahrenheit break it, and preserve in very close phials.

[This process will answer also for hydrate of soda.]

Potassium. In 1807 Davy placed some slightly-moistened pure potash on a platinum plate connected

with the negative pole of a powerful galvanic circuit; then bringing a platinum wire from the positive pole to the upper surface, gradually the potash decomposed, oxygen gas was solicited by the positive pole, while at the opposite, in contact with the platinum plate, appeared globules of a white metal resembling mercury; which, exposed to the air, very rapidly solicited oxygen and became encrusted with potash, which continued to absorb moisture and form a solution of potash. The metalline element in oxygen gas, at a temperature that would vapourise it, exhibits a white brilliant flame and intense heat, so combinative with other substances as to supply an idea of the alchemist's *alkahest*, or universal solvent.

By the like process SODIUM was obtained, and decomposition effected of Lithia, Lime, Barytes, and Strontia; whose bases, amalgamated with mercury, showed them as metallic oxides.

Here arises an important inquiry: Whence originates this general alkaline result of the evaporated ley of incinerated wood and vegetables?

The doctrine of the schools is, that nitrogen is either extremely sluggish, or completely indifferent, to combination in combustion. We find oxygen present in calcined metals, and nitrogen, or alkali, present in the results of incinerated wood, etc. Then, either the rather uncommon opinion of a few is correct, that nitrogen, or alkali, is a component of all vegetation; or, during the incineration, while the hydrogen fixes the oxygen, the carbon and smoke fix nitrogen and generate the alkali. We need more information on this subject than at present seems even to have been conjectured.

CARBONATE OF POTASH from the atmosphere so

rapidly solicits moisture as soon to become liquid (therefore termed *deliquescent*), and only is this water again dissipated at 280°. It has a milder savour and a weaker action on woollen fabrics than the hydrate, yet by it similarly are vegetable blues rendered green. In a silver crucible at a high temperature it fuses, and is volatilised without its carbonic acid being separated.

To determine whether the carbonate of potash is adulterated: In a certain quantity of water, by measure, try what quantity will dissolve; this will detect the sulphate of potash which is sluggishly soluble. To detect common salt use sulphuric acid at 1·141, of which 355 will saturate 100 carbonate of potash.

Process.—(1.) In water dissolve 100 grains, and gradually add the test till neutralised; the quantity of acid used proves that of real carbonate affected, because as 355 : 100 : : the weight of the test used : to the number required.

(2.) *To estimate the carbonic acid present in the alkali.*—Into a Florence flask put 4 ounces of water, by measure, and 100 grains of the alkali. Fill a phial with dilute sulphuric acid, and place both flask and phial in the same scale, which exactly equipoise by weights in the other scale; then gradually pour the acid into the flask until no more effervescence ensues. The weights will preponderate, and the number of grains needed in the flask scale to restore the equilibrium will be the precise weight of the carbonic acid evolved.

(3.) *Carbonate of Potash* (*for Tests*).—At a low red heat calcine bicarbonate, and all the water, with half the carbonic acid, will be dissipated.

It is proper, in glaze-making, to take into the account the greater volatility of potash than of soda, and of both when water is present, and likewise of boracic acid.

SODA.

SODA, in the state of hydrate, has a grey colour, and is hot, acrid, and bitter to the palate, to the quantity of 75 per cent. soluble in water, never like potash deliquescing into an oily-looking liquid, but by a portion of its water of crystallisation evolving, becoming in air a soft efflorescent substance, by soliciting the carbonic acid to combination as a carbonate. It possesses, in common with potash, all the alkaline (or anti-acid) potencies; it similarly changes vegetable blue and purple tints to green; but it is weaker than potash in combinative potency with the metals and the earths, needing a very high temperature to combine with the latter, and that continued some time with silica forms very perfect glass. It is the *nitron* and *nitrum* of the ancients, the *natron* of the Hebrews, and the *fossil* or *mineral* alkali of the 17th and 18th centuries, because it was supposed to be a peculiar product of the mineral kingdom. This error is now corrected. It is known to be obtained in a manner similar to that adopted for potash—lixiviating the ashes of incinerated marine vegetables, or those located on the sea-shore, which alone supply it in this form; and, as these plants fail to afford such results when they have been transplanted to inland situations, but supply potash, the opinion seems warranted that the soda of these plants is derived from the muriate of soda, by the roots appropriated during vegetation on the sea-shore. There is also considerable difference

in the quantity and quality of the products of plants of the same species from different countries. That it exists subterraneously in vast impure deposits in the bowels of the earth is demonstrated by the fact of its being usually, and to a large quantity, abstracted by active springs and running waters. Hence in some countries, as Hungary and Egypt, combined with carbonic acid it is obtained in immense quantities; and from the Trona lake alone upwards of 100 tons come into the market.

In its caustic state, whether supplied by the decomposing process detailed under the substance Potash (p. 216)—certainly a very ready one; or, by the combustion of excess of sodium in air only just sufficient for its conversion into this alkali, and with a high degree of temperature, the fracture is vitreous, the receptive potency sluggish, and a continued incandescence precedes its fusion. On adding a little water to the alkali violent action and reaction ensues, the alkali assumes a crystalline appearance, and becomes more fusible and volatile. When its solution is treated with tartaric acid, or muriate of platinum, no precipitate ensues as when applied to solution of potash.

Sodium requires a greater galvanic power than potash to decompose the pure hydrate. It has a beautiful lustre, like silver, fuses at 200° Fahrenheit, and at a state of incandescence vapourises. At the ordinary temperature of the atmosphere it scarcely affects dry air or oxygen; it has less potency than potassium in most substances, yet more slowly tarnishes, and like it is best preserved under naphtha. When heated and immersed in either oxygen or

chlorine it forms a most brilliant flame; and, cast on water, it causes violent effervescence, without flame, swims on the surface, with much agitation diminishes gradually, and forms a solution of soda. When burned in excess of oxygen, there is formed the peroxide of sodium, of a fine orange colour, very fusible, deflagrating with combustibles at a high temperature, and, when treated with water, its oxygen evolves, and there is formed, as before, a solution of soda. As far as they have been investigated, there seems much similarity in the action and reaction of the different combustible substances and gases on the peroxides of sodium and potassium. And when we recollect that of all the acidifiable combustibles sulphur most potently solicits sodium, I think, we need not be surprised at the glaze being rendered yellow whenever sulphurous vapours enter the seggars during the baking process.

Carbonate of Soda, the impure soda of commerce, obtained from Spain and the Levant under the Spanish name *Barilla* (that of the plant whence the Spaniards obtain it), is extensively used in this manufacture for the glazes of best earthenware and common porcelain, and also in those of the finest glass (as well as for soap, and for the processes of bleaching), etc., because of the facilities supplied by the very comminute state of ground flint, or silica in Lynn sand, for chemical processes to aid its combinative potency by a high degree of temperature. A great proportion of that employed by potters and by other Manufacturers to supersede potash whenever an alkali is needful, is now fabricated from common salt (as subsequently described), and

afforded at one-third of the expense formerly attached. A most remarkable fact is, that it has the like components as prussic acid, only with much difference in the respective proportions.

Processes.—(1.) By sulphuric acid convert common salt into sulphate of soda (after separating whatever portions are present of sulphates of lime and magnesia), which by ignition with saw-dust or pit-coal slack convert into sulphuret of sodium; either add lime or dissipate the sulphur by roasting and the sodium will become carbonate of soda. In open vessels let the lixivium rest, and after two successive crystallisations the results will be very fine.

(2.) To a solution of sulphate of soda add pyro-acetic acid and lime; during two hours keep up the ebullition, and the sulphuric acid of the liquid will enter into combination with the lime, while the separated soda is solicited to combination by the acetic acid. When the liquid is cool, filter, then evaporate dry, calcine the residuum, redissolve in pure water, evaporate till a pellicle forms on the surface, and then leave to repose, and the crystals of carbonate of soda will be formed.

(3.) *Hodson's Patent.*—Well-burned lime 3 cwt., slake with strong brine, and sprinkle until the salt accumulates on the surface; spread in thin layers, and when dry calcine to a reverberatory furnace. To this calc add 3 cwt. of salt, or salt-rock, and again calcine; next add 2 cwt. of sulphate of lime, and 2 cwt. of the supersulphate of potash, then stir in frequently two spadefuls of coke, small coal, or charcoal (every quarter of an hour at most), until are used 2 cwt. of charcoal, or 3 cwt. coke, or 4 cwt. small coal, then continue to raise the temperature during four hours; next draw out the mass, and when cold, break the calc into lumps for use.

Of the imported impure sodas of commerce the Spanish is best. It is dark bluish coloured (as in the best French), ponderous, sonorous, dry to the touch, and externally marked with small cavities, free from offensive odour, very salt savour, and by exposure to the air undergoes a saponaceous efflorescence. The

worst kinds have a fetid odour, and are white, soft and deliquescent. The respective values of the several kinds have not been determined by careful analysis, and the ease with which the article can be adulterated almost precludes the hope of any advantage from it. The relative excellence of the article depends on the absence, or the proportion present, of vegetable alkali, muriate of soda, sulphate of potash, also lime, magnesia, alumine, silica and even iron.

Many plants when incinerated, and the ashes levigated and evaporated, supply carbonate of soda, which varies in purity with the plant itself. Those of Spain and Africa supply 25 to 40 per cent., Smyrna 40, East India and Cape 45; whereas the Blanquette 8, and of some other European districts, from 8 to 12 only. At Alicante when the plants approach to a dry state they are incinerated, and this is continued with just sufficient ardency for semi-fusion, causing the result, of a superior quality, to concrete in cellular masses. The KELP supplied from the Orkneys, in quantity of more than 3000 tons annually, is the impure produce of the *fusi* family, which supplies only 3 per cent. of alkali. The British Barilla is from the *salicornia Europœa*, which supplies 2 per cent.

In pp. 59, 61, of vol. IX. *Scheerer's Journal*, are the two annexed processes:—

Phosphate of Soda.—In sulphuric acid digest calcined bones three hours to obtain the excess of lime; the phosphate of lime dissolve in nitric acid; add equal weight of sulphate of soda, and distil off the nitric acid; add great plenty of pure water, filter out the sulphate of lime, evaporate the liquid, and crystallise in the usual manner.—*Funcke.*

Sulphate of Soda.—Add water while forming a paste of 8 parts

of boiled plaster of Paris, 5 of Ball clay, and 5 of common salt; this paste incandesce six hours, pulverise the calc, mix in plenty of pure water, strain through a flannel bag, or strong filter, evaporate, and as usual crystallise.*

Carefully add sulphuric acid to a solution of carbonate of soda; during brisk effervescence carbonic acid gas evolves, and by discontinuing the dropping in of the acid at the instant when the effervescence ceases, the liquid, if examined, will be found warm and devoid of aciduline or alkaline properties; neither sour, acrid, hot, or corrosive; not affecting vegetable blue colours, but a compound whose two components have neutralised each other's potency or momentum. Yet the compound has peculiar qualities; it is slightly bitter, saline, and cooling; much employed in a crystalline form, as Glauber's salt; the liquid is evaporated to a certain specific gravity, then left to repose, and while the liquid continues at the ordinary temperature of the atmosphere, the compound atoms arrange themselves in regular figures.

Common salt, intended for the glazing of coarse pottery, should be free from muriate and sulphate of magnesia and sulphate of lime, as each has its peculiar yet deleterious effect on the ware. The salt melts in a red heat, and at a white heat it evaporates

* In the *Operative Chemist*, p. 264, Mr. Gray gives a hint, which, as I regard it to be valuable, in reference to filtering, I have amplified, and for the benefit of colour-makers especially, I have particularly described it:—

Take one of the conical water-closet pans, in the clay state, and fit to it a grid pierced with half-inch holes, slanting towards, all up to the flange; adapt to this vessel a strong funnel to bed to the flange; fix these in a firm support over the vessel which must receive the liquid. Inside the cullender place a coarse linen-cloth, previously wet with pure water, and over this lay a damp sheet of filtering paper. Into this vessel then gently pour the liquid to be filtered, and neither loss nor danger will result, if ordinary care be employed.

in a white smoke, yet without undergoing decomposition.

The employment of it in the dipping-tub, to increase the specific gravity of the fluid, and intended to keep the lead in suspension, is a very questionable practice, even if the volatilisation of the muriatic acid by baking was not injurious to the glaze.

On the subject of hydrates there is a difference of opinion. In those whose proportion of water has been accurately determined, the hypothesis of Lavoisier has been supported by the oxygen in the oxide proving to be exactly equal in quantity to that in the water. Yet there is a possibility of the existence of sub-hydrates with only half the proportion of water present; also super-hydrates, with twice or more times this quantity. Who will affirm that the crystallised forms of potash, soda, barytes, and strontia are not super-hydrates? Berzelius—no despicable authority—regards that of barytes as barytes 1 + 9 water.

Because at the heat which melts plate-glass sodium becomes fixed, its oxide, soda, is a very useful component of good glazes, causing the others to readily flow during the baking, without streak or bubble, and yet remain equally durable and permanent when cold.

LITHIA.

LITHIA has scarcely been known as a hydrate, and is in fact the *alkali of stone.* Like potash and soda it has a white colour, and vegetable blues and purples it renders green; the savour is acrid, like that of potash, but the caustic effect on the tongue is less corrosive; in the air it continues dry, and abstracts not moisture, like potash, but carbonic acid, and becomes opaque or efflorescent. Its solubility in cold water, as a carbonate, is to potash and soda as 3 is to 10 p. and 7 s.; the watery solution effervesces with acids, separates the solutions of salts of ammonia, metals, and alumine from magnesia; is scarcely soluble in alcohol, but this being added to the watery solution, after repose of several hours, precipitation of carbonate of lithia ensues; likewise when a solution of carbonate of soda is mixed with that of lithia. It becomes caustic, like potash and soda, by lime being presented to appropriate the carbonic acid. Its nitrates and muriates are deliquescent, and it appropriates more water for saturation than potash or soda. It is not precipitated by the alcoholic chloride of platinum. When in a silver crucible closely covered, at a red heat it becomes transparent by fusion; and after being at a white heat during an hour, the bulk is found the same, but the alkali is affected by the carbonic acid of the air. If a platinum crucible be employed, the alkali powerfully solicits the metal to combination. Its great combinative potency with oxygen has prevented a full investigation of the metallic base. The proportions with which they combine are 1 to 1, and the atomic weight is 1·25.

Process.—Into a silver covered crucible put the mixture of 1 part pulverised petalite or spodumene, or white felspar, and nitrate of barytes 4 parts; in excess of muriatic acid digest two hours to dissolve the mass, then filter out the silica, and wash the filter well; add test 24 to appropriate all the barytes and displace the muriatic acid; again filter out the barytes, and wash the filter, and evaporate dry the filtered liquid; the residuum again dissolve in water, filter, and alkalinise with test 3 to precipitate the alumine, which filter out; wash the filter, and again evaporate dry, and raise to a low red heat; again dissolve in water; any sulphate of lime present is insoluble, sulphate of lithia is soluble; add barytes water to appropriate the sulphuric acid, evaporate the water, and the residuum is lithia, or add acetate of barytes, filter, evaporate dry, and calcine for carbonate of lithia.

CALCULATION OF CHEMICAL SEPARATIONS.

A substance composed of known proportions of two elements—*a* the quantity of one component united with *b* that of the other—is placed in contact with another substance which solicits one of these elements to combination; B the quantity of the solicited element combining with A, that of the agent. (The quantities regard the *same* unit of volume or weight.)

Often is it needful for a salt, with *a* of acid united to *b* of base, to be separated by a stronger acid to form a fresh salt. And whether the separations affect simple or binary compounds we have to determine as nigh as possible the water probably present, and then take for the connective of the new and the old compounds either the acid or the base.

Problem I.—How much strong acid will separate the quantity P of the proposed salt? The formula is: b A P $\div$ B $(a + b)$ = the quantity of acid needed; and the fresh salt will weigh P b (A + B) $\div$ B $(a + b)$.

Problem II.—How much of the proposed salt must be employed to appropriate the quantity P of the strong acid? The formula is: B P $(a + b) \div$ A b; and the fresh salt will weigh (A + B) P $\div$ A.

They are practically applied to decomposing common salt by sulphuric acid for muriatic acid, also sulphate of soda, thus: Dry chloride of sodium is 9 chlorine and 6 sodium, and sulphate of soda is 6 soda + 4 sulphur + 8 oxygen; the water present is 56 per cent., and the sulphuric acid has 20 per cent. To determine the quantity of sulphuric acid required to solicit to combination the soda present in 25 lbs. of common salt: $a = 186{\cdot}38$ muriatic acid; $b = 100$ soda; A = 100 sulphuric acid; B = 78·187 soda; P = 25 common salt; and we get, $\frac{100 \times 100 \times 25}{78{\cdot}187 \times 186{\cdot}38} = \frac{250000}{14572{\cdot}49} = 17{\cdot}15$ lbs. dry sulphuric acid; to which add one-fourth = 4·28 lbs. for water present, and the required quantity is 21·47 lbs. And the resulting weight of sulphate of soda, by the same data and the second formula, $\frac{25 \times 100 \times 78{\cdot}187}{78{\cdot}187 \times 186{\cdot}38} = \frac{445467{\cdot}5}{14572{\cdot}49} = 30{\cdot}5$ lbs. sulphate of soda; to which add 39 lbs. water as present in the crystals, and we get 69·5 lbs.

Again. We may wish to know precisely the quantity of dry common salt separable by 25·5 lbs. of strong sulphuric acid, containing 20 lbs. of dry acid.

The first formula of the second question in numbers gives $\frac{78{\cdot}187 \times 20 \times 186{\cdot}38}{100 \times 100} = \frac{291450}{10000} = 29{\cdot}14$ of common salt. The same data, for the second formula, in proper numbers will show the resulting weight of dry sulphate of soda, namely $\frac{178{\cdot}187 \times 20}{100} = 35{\cdot}64$ lbs., to which add the water proper, 45·36 lbs.; for as 44 dry sulphate is to 56 water in crystallised sulphate, so is45·36; and 35·64 + 45·36 35·64 to = 81 lbs.

CHAPTER IV.

THE EARTHS.

This class includes those mineral substances which compose the crust of our globe. In a pure state they are incombustible, without savour, or odour, or colour, or potency to change the blue or red tints of vegetables, or their juices.

The strata and debris which form the surface of our globe present earthy substances with seeming countless variety; but the rays the lamp of chemistry sheds on them surprise us with the fact that all we tread beneath our feet—whether stony, or in powder; a range of Alpine hills, or a few isolated gems; a succession of valleys, or a tract of verdant plains; the immense mass of the rock, or the minute specimens of the cabinet—are results of different quantities, relative numerical proportions, mechanically intermixed, or chemically combined with each other, of only these elements—Barytes, Strontia, Lime, Magnesia, Alumine, Silica, and these of rare occurrence, Glucina, Zirconia, Yttria, Thorina.

Barytes, strontia, lime and magnesia are called *alkaline*, because they affect slightly certain

vegetable colours, much like the alkalies, and have varied combinative potency with the acids; the others are called simple earths, because they do not present either alkaline or aciduline properties on tints, or chemical combination with the acids.

The *alchemy* of Davy has completely subverted the previously prevalent opinions of chemists concerning the earths in the purest state Nature or Art can supply them. Their peculiarities render them the connecting link of the alkalies to the metals. For like the alkalies the earths act as bases, solicited to combination by the acids, and forming peculiar salts, usually with completely distinct properties from those of either acid or base, insoluble, or only with difficulty soluble, in water; and like the metals, indifferent to volatilisation by heat. The most probable analogies show that they are oxides of certain metals, into which, however, they are not convertible by all the usual methods of reduction, and when so reduced by the most improved suggestions of scientific research, the result possesses merely an evanescent metallic existence, even if it be hereafter proved that metals are not merely unoxidated earths, or that there is clear dissimilarity of composition in alkalies, acids, native metals and metallic ores. Their metallic bases more nearly approximate to the common metals than do those of the alkalies, and themselves more closely than the alkalies resemble metallic oxides.

On these subjects, and others correlative, certainly we are now on the eve of great discoveries. There is known to be present with all pyrites, usually in considerable quantity, an unmetallic

substance, or earth, which seems to be intermediate between earth and metal; yet to this latter state current processes have failed to reduce it, as likewise to determine its peculiarities. Under the metals I have suggested the probable *modus operandi* of their formation, to which I must refer the reader who does not clearly understand the following detail: This globe appears to have been partially under galvanic influence, and thereby pre-disposed to become metalline; but either there has been a cessation, or defective potency, of that agent in the production of all metals, or it has not been sufficiently long continued to perfect the degree of change needful to elaborate the metal. For suitable information on this subject, in vain have I examined every modern work on chemistry to which I could gain access. It is to be regretted that chemists of the greatest ability have devoted so much attention, or exhausted their energies, in mooting abstract points, only useful in a scientific not practical application; those who have occasionally attended to the resolving of the combinations of the earths as yet do not appear to have more than merely, *en passant*, directed their thoughts towards the researches much more useful in the Arts of Life —the fusibility or infusibility, and other chemical properties of the earths and stones. Not so was the custom of their predecessors, however tainted with fondness for alchemy—Imperatus, Hiærne, Wallerius and Pott. Much original information on these subjects is given in the First Chapter of the Second Part of this Work.

ALUMINE.

ALUMINE in a pure state (as in the very rare corundum gems, the oriental sapphire and ruby, with a little colouring matter) is without odour or savour, fusible by the oxy-hydrogen blow-pipe only, and soluble in test 1, and solution of caustic soda, whence it is separable by the acids as a hydrate. It does not affect the tints of blue vegetables, nor their juices. Its absorbent properties capacitate it for rapid combination with the colorific oxides of metals, and it is frequently mixed with cobalt protoxides; also much used as a component of powders to cleanse away oils.

Alumine is regarded as the oxide of a metal named aluminum, because the earth is the base of the salt *alum*. Only in very recent times have the researches of Davy led to its development as a compound of a peculiar metallic base with oxygen.

Processes.—(1.) *Pure Alumine.* In 20 parts of warm distilled water dissolve 1 part of good alum; then carefully drop in solution of carbonate of soda to precipitate any spice of iron possibly present, and filter it out; to the supernatant liquid add test 2, and by it soliciting to combination the sulphuric acid present, the earth in white flocculence will freely precipitate. In its moist state it is appropriated by the Manufacturers of printing blue. For other purposes, filter out, wash well, dry at a white heat for not less than one hour, to dissipate the moisture and any sulphuric acid possibly present.

(2.) *Aluminum.* In a porcelain tube incandesce pure alumine while a current of chlorine gas passes through to form a chloride of alumine, which mix with potassium in a platinum crucible;

cover close up, raise the temperature very high, and the chlorine will convert the potassium into potash, which, with aluminum will remain in the crucible. The metal has resemblance to platinum, with the brilliance of tin. When incandescent it is soluble in dilute sulphuric or muriatic acid, and forms a very hard and refractory button of alumine. The galvanic circle supplies similar results.

Alumine exists more or less in almost every mineral, and is one of the components most in quantity present in clays, ochres, loams, boles, fuller's earth, soils, rocks and strata of our globe. In its pure state it is without grittiness between the teeth, a smooth paste, soft to the touch, adhering to the tongue, not soluble in water, yet combining with it in every proportion, and at intense heat retaining a portion thereof, at every degree above incipient redness; from the loss of water there is definite contraction or reduction, its volume being condensed, not a portion fused (except in consequence of the presence of water generated during the combustion of the gases of the oxy-hydrogen blow-pipe); after this baking scarcely can it be placed in the balance scale ere its absorption of moisture from the atmosphere increases its weight; in a dry one to 15 per cent., in a humid one to 33, and saturated to 51 and 54, and it retains 50 per cent. at the ordinary temperature of the atmosphere. Moistened with water the mass is cohesive, tenacious, ductile; and this plastic property capacitates it for being kneaded into regular shapes for vessels, or moulded into figures, which are rendered hard and durable by the process of baking biscuit and glaze.

At very high temperatures alumine combines

with the fixed alkalies and with most of the other earths, a greenish and bluish tint characterising the results of barytes or strontia. In ammonia alumine is scarcely soluble, and not at all in solutions of alkaline carbonates. With barytes or strontia it forms two very distinct compounds: one, an insoluble powder with plus of alumine; the other, a soluble salt, in solution, with plus of the alkaline earth.

CLAYS.

THESE aluminous minerals (for whose discrimination into species we yet need a clear and distinctive characteristic) are very extensively distributed in the outer surface of the crust of our planet, and consequently are readily available for different Arts of Life in which they are useful. They occur in opaque, non-crystallised masses, with a dull, even, earthy fracture, easily scratched by the nail or iron, and because of an adventitious substance present (oxide of iron as a spice, but never as a component), when breathed on they exhale the peculiar odour called argillaceous or *earthy*, not perceptible in alumine or pure clay; when pressed to the tongue adhering closely, and imbibing the moisture, so as not again to resign it until the temperature is raised very high, retaining 10 per cent. at 300° Fahrenheit. Because of this tenacity of moisture, they readily are worked together into a plastic paste for the various purposes of vessels, figures, tiles, bricks, etc.

The species named *Black Clay*, because of the presence of much carbonaceous ingredients, is further distinguished by the peculiar property of evolving all these during the intense heat of baking biscuit, and becoming whiter in proportion to the quantity present. It is usually mixed with one or more of the other species. The *Cracking Clay*, so named by the Brothers John and Thomas Wedgwood, of Burslem, can be used only with much care of mixture with the other kinds, and with flint, when it bakes very white and makes firm ware. The *Brown Clay* requires to be a long time exposed to the alternations of the weather for disintegration, else it will not pass through the lawns. The process of baking biscuit renders it extremely white, and it is entirely free from the disadvantage mentioned of the previous species —cracking while baking. Yet it is not constantly introduced, because Manufacturers not acquainted with its peculiar properties from its components and proportions (a small spice of phosphoric acid that renders needful the presence of some component with potency to neutralise its action during the baking biscuit that the lead of the glaze be not thereby injured) have hitherto failed to divest it of the potency to cause crazing. In some porcelains it is very partially introduced in preference to the *Blue Clay*, which is most used, because, whether in flint ware or porcelain the baking biscuit is followed with a whiteness (increased by more flint than any of the other species will appropriate), a solidity of fabric, and without the liability of the other kinds to crack during or after baking. However comminute we render any of these clays after once baking, the

cohesive property, on which depends the plasticity, is absent until a solution is formed in some acid, and an alkali causes precipitation. This has caused the opinion that in their native state a gluten is present, which heat destroys ; and it is further observed that the alkalies themselves have trifling combinative potency with the clays (or alumine) compared with that in silica.

The following are the most correct analyses I have been able to obtain of the clays and other earthy minerals employed in this Manufacture :—

		Silica.	Alumine.	Iron.	Lithia.	Lime.
Common Pottery Clay, per cent.		60	33	3	—	3·5
Ball Clay, Blue	„	64	35	1	—	—
——— Black	„	66	30	2	—	—
——— Brown	„	67	30	2·5	—	—
——— Cracking	„	68	31	1	—	—
Cornish Grauen	„	68	16	2	14	—
——— Clay (China)	„	71	28	·5	·5	—
Felspar, Kaolin	„	68	20	·5	12	—
——— Petuntse	„	60	20	—	20	—
Flint	„	98	1	·1	—	1.

SILICA.

SILICA (from the Hebrew *selag*, to burn or vitrefy, whence also our word *slag*, something vitrefied), an oxide of a peculiarly-combustible element, is a very white, fine powder, without savour or odour, but a harshness when rubbed between the thumb and finger, and a grittiness between the teeth ; not glutinous when moist, retains about 26 per cent. of water at the temperature of 70° Fahrenheit ; is insoluble in water alone, yet is held in solution in the waters of the Iceland Geysers ; others precipitate it as stalactites ; and it is secreted in the rinds of grasses and equisetums as tabasheer. It is fusible by the oxy-hydrogen blow-pipe, also with 3 parts caustic potash, and 4 parts carbonate.

Silica is very abundant in Nature, probably more so than all her other products together. It is the chief component of all silicious minerals and scintillating stones ; the great proportion of oxygen present renders its combinative potency much similar to that of exhibited acids ; in many of the gems it has a spice of metallic oxide, either chemically combined or mechanically mixed. As quartz it occurs, in an almost pure state, in those large regular forms resembling glass, and known as *Rock Crystal ;* and in a less pure state we find it in immense masses, beds, and elevations alone, and likewise in the primitive mountain chains, in granites and the other kinds of rocks. From these, by mechanical separation, it forms the well-known article of sand on the

sea-shore, the banks of rivers, and the low plains; and while alumine appropriates and holds water, silica, in this state of sand, allows it to permeate, filter itself from impurities, and become again suitable for all the purposes for which it is intended by Nature. Its peculiar combinative potency renders it not obviously soluble in water, but its real solubility is clearly demonstrable in Nature, by the numerous crystals elaborated, and artificially, by the facts adduced by Berzelius; and further, that whenever the compound result of fused silica 1 and potash 4 is dissolved in water, and this solution is much diluted with an additional quantity of water, the silica, as 1 to 1000, continues suspended therein, and is not precipitable by any acid or quantity thereof which may be supplied. This is the true cause of its intimate combination with the earths and alkalies.

Process.—Silica is supplied in a pure state by the residuum of fluor spar heated in sulphuric acid, by which fluorine evolves. Also by this process: Take a small nodule of well-burned flint, as white as is readily obtained (or rock crystal, or quartz), crush it in paper, and triturate in a porcelain mortar to a fine powder, in observance of that chemical law, that to facilitate solution we bring solids into a comminute state, that we may thereby increase the surfaces submitted to the solicitings of fluids; mix it with caustic potash 3, or carbonate of potash 4 times its weight, and for the former use the silver crucible, for the latter, one very capacious of earthenware; slowly and gradually raise the temperature to a strong red heat, and during forty minutes keep in this heat, and with an iron rod preserve the effervescence sluggish; then pour the frit upon a dish of brass or copper, and when cold again pulverise. Dissolve in pure water, filter, and carefully pour into excess of diluted sulphuric or muriatic acid (not the acid pour into the solution, else *glass*, not *silica*, will be the precipitate), or into a solution of muriate of ammonia, which will not dissolve any

portion whatever of the silica. Let the liquid repose not less than twenty-four hours, then decant by a siphon, wash the precipitate well with hot pure water, till all savour of acid and alkali is removed; then evaporate dry. For the alumine possibly present, boil twenty minutes in sulphuric acid 5, water 5; filter, wash well again with hot water, evaporate dry, and incandesce the result. In this pure state it is refractory in the highest heat of the potters' oven, and cases of its fusion have been ascertained to result solely from the presence of a small portion of alkali not previously recognised by the operator.

The silica thus obtained, carefully washed and well dried, is almost wholly indifferent to the action of every acid except the fluoric, which appropriates 65 per cent., and therefore so forcibly acts on glass; but it is readily solicited by a boiling solution of caustic potash, soda, lithia, barytes, or strontia, and the silicated potash by a boiling aqueous solution of barytes, strontia, or lime, with alumine; yet the liquid is active on turmeric paper, and renders it brown. The solution, evaporated, dried at 242° supplies a substance pale yellow, transparent, deliquescent, soluble in water (silica 2, soda 6, water 1), and the concentrated solution is gelatinised by the supply of acid equivalent to the soda.

Silicium.—Mix dry silicated fluate of potash 2 parts with potassium 5; fuse in a porcelain crucible; the hydrogen will evolve, and pure silicium will result, a brown powder, resembling charcoal in combustibility, varying with the state of aggregation; and in its densest state it may be incandesced without flame resulting. With some difficulty it is completely combustible—with carbonate of potash; in vapour of sulphur, into a grey sulphuret; in chlorine, into a limpid colourless fluid, with the odour of cyanogen;

but not heated with nitre. To form silica it combines as 200 with 208 of oxygen.

The composition of silica is best determined by the experiments of Berzelius and John Davy. Berzelius reduced silica by iron and charcoal; in muriatic acid separated the alloy of iron and silicium, which latter combined with much oxygen. After determining the quantity of red oxide of iron, of carbon, and of silica supplied by the alloy, he supposed that silica has from 45·34 to 47·75 per cent. of oxygen. Stromeyer, by a different analytical process, concluded that it was 55 per cent. Dr. Davy's analysis of the triple fluate of silica and ammonia is, ammonia 24·5, silica 46·357, fluoric acid 29·143. Now the oxygen of the ammonia, here the smallest quantity, must exist in the silica in some multiple of a whole number. But 24·5 of ammonia contain 11·219 of oxygen, and the silica contains, in 46·35, 22·35 of oxygen. But $11{\cdot}219 \times 2 = 22{\cdot}438$. These show how near to the absolute truth is the result supplied by Berzelius; while the probable accuracy of Davy's conclusions shows the impossibility of silica containing 55 per cent. of oxygen. Again, Ekeberg's analysis of ytterite, most exact in its details, supplies yttria 55·5, silica 23, oxide of iron (as by the analysis) 16·5, equivalent to 15·42 of pure black oxide of iron. Yttria 55·5 has 10·3 of oxygen, silica 23 should have 10·9, and the black oxide of iron 15·42 has 3·5; now $3{\cdot}5 \times 3 = 10{\cdot}5$. As the silica, whenever present with other components, must be in strict accordance with the laws of definite proportions, the coincidence just mentioned is an additional proof how near to the truth approximates this determination of the composition of

silica. As it contains more than one volume, and cannot be three volumes, the probability is that it is two. This great quantity of oxygen present in silica is one chief cause of its great utility in several of the Arts of Life, and of its important introduction and beneficial employment in the Manufacture of fine earthenware, porcelain, and glass, because of its ready combination with an alkali.*

* No person who knows Mr. Donowan can doubt that his knowledge of philosophical chemistry is very extensive. However, to his celebrity the volume on the Manufacture of Porcelain, in Dr. Lardner's Cyclopædia, will not make any addition. Every potter of ordinary acquirements will immediately denounce its total deficiency of correct information. In his remarks on the defect of ware, *chipping off the edges*, he states, that "the Chinese prevent this by applying to the edges a mixture of charcoal [of bamboo] powder and the glaze; and when this is very dry the vessel is covered with the glaze and baked." He opines that it might be of great advantage to our Manufacturers to attempt something of this kind, and for the purpose suggests the charcoal of green elder. He does not assign any reason for the Chinese practice, that is, to supply additional fuel, that in the same time of baking it may properly fuse the thick components of glaze supplied to the edges. Neither does he once seem to have troubled himself to reflect on the great differences in the processes of King-te-ching and Stoke-upon-Trent. He does not answer, because he has not asked himself, these questions: Are English porcelains liable to similar injuries? and, What chemical effect does the charcoal produce? He mentions the caution used in preparing the bamboo—that the rind is peeled off, else the edges would burst in baking. Still it has not occurred to his mind that the silicic acid of the tabasheer of the rind, when its momentum is excited by the high temperature of the potters' oven, would render very brittle, and therefore of easy fracture, the glass resulting from its combination with the alkalies present. This is the real cause of

The almost general and constant momentum, in some multiple of 4, of the combinative potency of silicic acid on the alkaline earths in natural primary mixing, as well as metallic oxides, and in like manner determining them in series, also continuing its potency when other acids have been exhibited to produce separation, fully warrant the method herein adopted of mentioning the numerous proximate components of the many and various natural silicates of alumine, in series, of simple combinations, and complex compounds, the more clearly to develop the composition of silicious minerals.

Each silicious mineral must of necessity be compounded of the like number of silicates as there are receptive atoms, those of oxygen; each of which is accompanied by other two active atoms, with the antagonist potency of hydrogen, on the general principle of separation and reunion, the mechanism of atoms and of Nature. In each silicate the oxygen atoms are precisely a third of the total number present; there must be likewise the same number of atoms of silicium, and also the like number of atoms of the other element which distinguishes the silicate. Want of a clear understanding of this fact, probably, has not diminished the errors of the Manufacturers. Even to the present day, on no analysis of the clays,

the Indians producing fire by rubbing together two pieces of bamboo; as both have a coating of silica in their tabasheer, sparks result from the friction, in like manner as from rubbing two pieces of quartz together, an effect produced even in water.

silicates of alumine, with which they are supplied by dealers, can they place confidence, because not yet has any explanation been published whether the silicium, alumine, and oxygen are present in only simple or in double or in triple proportions of combinative potency, and number of elements. What I wish to be understood is, that of the five kinds of clay—blue, black, brown, cracking, and Cornwall—they have no statement whether any, or more than one, and which, as a compound has for its components one *particle* each of silicium, aluminum, and oxygen, equivalent to a hydrate of aluminum; or of 2 oxygen, 1 aluminum, and 3 silicium, a double silicate, of 1 particle of silicic acid and 1 particle of silicate of aluminum; or of 3 oxygen, 2 aluminum, and 4 silicium, a triple silicate, of 1 particle of silicic acid and 2 particles of silicate of aluminum; and in like progression.

		Al.	Sil.	Ox.
Silicate of Aluminum	Al. Ox. Sil.	4·5	4	8
Double Ditto	Al. Ox. Sil. + Sil. Ox. Sil.	4·5	12	16
Triple Ditto	Al. Ox. Sil. + Sil. Ox. Sil. + Al. Ox. Sil.	9	12	24

The determinations of these peculiarities are not mere ideal speculations; they are of vast importance to the perfection of the Manufacture, which must progress with the knowledge of all the materials employed. And yet the chemists of our day have been so occupied with regularly playing off a number of *occult* terms, for show of knowledge, that they have scarcely attended to the facts obvious to

common observers, nor allowed themselves leisure and opportunity to investigate the mechanical processes of Nature, that I cannot help the dread, that for another age, and for results of experiments instituted expressly for the purpose, is reserved the credit of throwing that light upon these subjects, which, for them to be accurately known, is indispensable.

FLINT.

FLINT is obtained in large supplies, to more than 100,000 tons per annum, from the vicinity of Gravesend, Brighton, the Isle of Wight, and the south-east coast of Ireland. In the form of nodules, frequently approximating to a globular figure, of sizes from that of a small apple to that of a cabbage, flint is found in horizontal strata of chalk, varied in fineness and solidity; and as the strata do not wholly touch each other, there is no solution of continuity between the upper and the lower. When first quarried the nodules always have a white opaque crust, of an earthy, chalky appearance, in thickness varied to two lines, with a loose texture, and much less hard and heavy than the flint which it envelopes. And after this coating has been removed, the action of the atmospheric phenomena ere long again covers the nodules with a second but extremely thin coating. Vauquelin took some time to discriminate whatever difference existed between flint and quartz, and he was convinced that there is essential difference, by him conjectured to be in the proportion of combustibility of each.

The best flints are not very large; in colour blackish-brown; the fracture has a greasy aspect, a little shining, with the grain so fine as to be imperceptible; specific gravity 2·594; and having these elementary atoms, according to both Klaproth and Vauquelin: Silica 98·, Lime ·50 (or 51), Alumine ·25, Oxide of Iron ·25, Loss 1· (or 1·1) = 100.

Flint occurs in great plenty in common chalk, in which it is deposited in tuberose masses, and in pretty regular layers, each in an insulated state; also occasionally in veins in primary and transition rocks.

The colour is usually grey, mingled with black, brown, yellow and red. Fracture perfect and large conchoidal. When cavities occur in it they are sometimes lined with small quartz crystals having the usual form; lustre glistening or glimmering, translucent; blackish varieties, only so on the edges. Hardness superior to rock-crystal, very fragile, and easily broken by a smart blow; specific gravity 2·575 to 2·594, 37 atoms silica = 74 + 1 water = 1·125 = 75·125. The alumine and iron merely spice the silicate.

The manner of Nature's formation of flint is a difficult geological problem; and only will it, as also that of chalk, be fully elucidated by intimate acquaintance with the applications of chemical combinative momenta with respect to mineral products. Both must have been produced by states of the earth and atmosphere, which we only can imagine, but not demonstrate by present facts. Some persons have supposed flints to be concretions of organic remains; and Hacquet has laboured to show that it originates from chalk, and is daily forming. Cavities in the chalk are filled with nodules of flint. May we regard these cavities as formed by gas evolved during the deposition of the carbonate of lime modified to form chalk, and while too impotent to reach the surface, sufficiently potent to prevent the congestion of the mass? Have the silicic acid and water permeated

and filled these cavities, and therein remained until solidified? One of my sons accidentally broke a nodule of flint (still in my possession), which demonstrates its having been formed by infiltration, whatever may have been the way in which the silicic acid came in contact with the lime. The nodule is elongated and hollow; and its interior presents an entire coating of minute crystals of quartz with a slight discoloration from a precipitate of protoxide of iron. I cannot but believe, that among the great quantities of flint nodules daily broken by hand for the mills, numerous instances are presented to verify my remarks, although they pass unnoticed.

The introduction of flint into earthenware, along with the finer clays of Devon and Dorset, greatly promoted the whiteness of the ware; although I must acknowledge that uncalculated losses have ensued therefrom, because of inattention to the precise quantity which would accomplish the desired purpose, and of want of acquaintance with its chemical properties. The merit of this introduction is, by the general voice of the Staffordshire potters, assigned to Mr. Thomas Astbury, of Shelton; and it is not too much for us to have expected that by the natural bent of his genius he would have been much more swayed, and would with indiscriminate ardour have introduced every substance adapted to advance the Art towards perfection. He can be excused only on the ground of its possibly requiring efforts greater than could be made by a person circumstanced like him, to place himself in array against the prejudices of the times, and for the practices of his compeers

evince a disregard, exceeding what is warranted by the current sum of philosophical knowledge.

The demand for his ware caused Mr. Astbury, in 1720, to take a journey to London on horseback. Ere he reached Dunstable his horse's eyes became so disordered as to threaten immediate blindness, so that on arriving at his inn he sought assistance from the hostler for the disease, which demanded prompt attention. The hostler put into the fire-grate a small nodule of flint—plentiful in that neighbourhood—and after it had become incandescent, he threw it into water and then pulverised it into a very fine powder, a little of which was blown into each eye of the horse, and the copious discharge which ensued relieved and cured them both. However, the attention of Mr. Astbury had been further engaged; he had noticed the white appearance of the calcined flint, the methods by which this, and its very fine state as powder, were so easily attained; and rightly conjecturing that its introduction as one of the materials in his Art would improve his ware in whiteness, he caused some of the coarse flints to be forwarded to Shelton, where, on his return home, he had them fired after the ware was baked, then pulverised in a large mortar, and in the state of powder mixed with pipe-clay in water, with which he *washed* the inside of his hollow-ware; and ultimately it was introduced into the body.

All the notices by tradition supplied concerning this person agree in the remarkable particular, that although his intimate acquaintance knew him to be very ingenious and acute, yet he managed to play

his part as the *most noted fool* employed by Messrs. Elers at the Bradwell Manufactory. Convinced that the development of their processes would render an important benefit to his countrymen, as well as to himself, he undertook the task for which he was well capacitated; he humbled himself, and without apparent regard sustained every kind of insult and contumely which the others, masters and workfolks thought proper to manifest towards him. He completely succeeded in his object, became a Manufacturer, and after his introduction of flint, his success was much greater than he might reasonably have expected. Yet his real modesty prevented that justice being done to his merits by his contemporaries which will be readily and willingly awarded by posterity.*

* As the details are rather remarkable, I make no apology for stating them, as communicated to me by an old potter of 84 years of age, in 1810, and also by Mrs. Smith, Astbury's granddaughter, of Lane-End, in 1814, having been introduced for this purpose by Mrs. H. Close, of Hanley. Aware that the Messrs. Elers employed only the most weak-minded persons with whom they might meet, lest their manipulations and processes should be divulged to the Manufacturers of Burslem, and knowing his own command of temper would enable him to accomplish his design, Astbury attired himself in suitable apparel, and with a complete idiotcy of countenance and expression, presented himself before the Bradwell operatives. His disguise was so complete as to render him unknown to his neighbour Twyford; and although it was attempted to drive him away by cuffs, kicks, and varied unkind treatment, from masters and idiotic workmen, he submitted to all with ludicrous grimace, and evinced so small a modicum of mental ability that he was employed on the premises. Whatever food he obtained was always *devoured*, and only his fingers were used to convey it to his mouth; he could not recollect

Flint is supplied in a liquid state to the Manufacturers in tubs of 40 pecks, of 8 Winchester quarts ;

any directions given him how to perform any of the labours required, but merely could assist any other person ; in few words, he sustained the character of the idiot almost two years without being discovered, and during that period he regularly registered every process he witnessed, and manipulation in which himself or others were engaged ; made models of every implement needed ; and acquired all the information requisite and useful in the peculiar Manufacture pursued by Messrs. Elers. A fit of sickness supplied opportunity for Astbury to quit their employment and resume his true character.

A remarkable coincidence I cannot help mentioning. Very early in the eighteenth century, a Mr. Edward Allgood, chief director of the Iron Works at Pontypool, South Wales (which had been commenced by his ancestors, but were become the property of a Major Hanbury, from some source not stated), obtained information that peculiar methods for polishing wire were practised by the operatives at Woburn in Bedfordshire. This much excited his curiosity (considering himself remarkably clever), and interest rendered him extremely desirous to become acquainted with these processes. He applied, accordingly, to several of the parties for this particular information, but in every instance experienced a mortifying refusal. Determined, in despite of every obstacle that might be presented, to obtain the desired object, he left Pontypool, and when arrived in the vicinity of Woburn, he disguised himself in the garb of a low mimic and buffoon ; and sustaining the characters with unusual good humour and effect, as he passed through the town, his ludicrous and amusing antics gradually gained him the attention and contributions of the workmen ; the repetitions supplied opportunity for a little familiarity, and procured frequent ingress to the workshops most celebrated for excellence of productions ; in these he witnessed, at the same time, the various processes and operations of the workmen ; and by waiting a suitable period he gained a complete knowledge as well of the manipulations, the machinery, and the requisite materials for fabricating the several kinds of wire.

or 64 scores, 1280 lbs. 32 lbs. per peck, 64 oz. per quart, and 32 oz. per pint.

When the slop-flint averages 32, or 28, or 24 oz. per pint, the proportions of flint and water are as follows :—

	Pint.		Quart.		Peck.		Tub.	
Pint at	Flint.	Water.	Flint.	Water.	Flint.	Water.	Flint.	Water.
32 oz.	21 oz.	11 oz.	42 oz.	22 oz.	336 oz.	176 oz.	840 lb.	440 lb.
28	14	14	28	28	224	224	560	560
24	7	17	14	34	112	272	280	680

These are readily verified. When three pints of slop-flint, at each of the respective weights, are carefully evaporated and dried, the results will be found 21, 14 and 7 ounces. Again, from a pint of water, at 20 ounces, abstract sufficient to admit 7 ounces of dry flint, and the mixture is found to weigh 24 ounces; when other 7 ounces are added, the weight is 28 ounces; and when a third 7 ounces are added, the weight is 32 ounces, or precisely that at which it should be supplied. And from this it will be clear, that if only a quarter of an ounce in the pint be wanting in flint, there will be 17½ lbs. deficient in the tub; and from this, and like causes, doubtless many errors have arisen in slip-making.

Potting.—As in preparing the calcined flints and felspar, for the pan in the mill, weight of pressure and percussion are requisite; the principle of the pile-engine is adopted—the falling with acceleration of a loaded beam or pestle, shod with iron ends. On a strong shaft are fixed single arms, placed a few inches

asunder, and forming the radii of a hexagon; on the end of each, at a right angle, is fixed a stout plug; and the motion of the shaft brings the plug of each arm in succession beneath another plug firmly fixed on the beam, or *stamper*, and after lifting the beam a certain height, quits it, and the weight of the beam by atmospheric pressure also brings it down on the minerals upon the strong grate, and as they are crushed they fall through, ready to cast into the vat.

In the noise of the stampers of the crushing process their rebounding is comparatively sonorous, occasionally at other times a dead blow; but on a first visit the shock on the nervous system baffles description; there is caused a painful jarring, the sense of hearing is much affected for some minutes, the attempts to converse are superseded by the voice being incapable of audible articulation; and some degree of lassitude is immediately produced.

LIME.

LIME, the very caustic protoxide of the pure caustic alkaline metal calcium—in its perfectly pure state as obtained by burning in a crucible at least two hours' time, at a white heat, calcareous spar, Carrara white marble, or clean oyster shells (which for *tests* should be closely bottled from air)—is white, moderately hard, easily pulverised, has a peculiar odour, burning-hot savour, and corrosive potency on animal substances; specific gravity 2·3; the blue juices of vegetables by it become first green and afterwards yellow.

Neutralised by carbonic acid, as limestone, every part of the globe presents it in great plenty; it also occurs plentifully as marble, chalk, calcareous spar (coloured, or perfectly white and transparent), and stalactites. From the earliest ages, after being *burned into lime*, that is, kept some hours at a white heat, by which the carbonic acid gas is dissipated, and the caustic property again restored in *quicklime*, it has been known and employed with the addition of one-third of water as mortar, and in its application as cement it again becomes carbonated into artificial limestone.

When a little water is sprinkled on some dry fresh-burned lime it is solicited, when hot, at 212°, with the momentum of 0·00078, and when cold, at 32°, with that of 0·00152 (first noticed by Dalton, one of the few original thinkers); much vapour arises, and the heat evolved is about 800°, which would ignite

some inflammable substances; the mass falls into a protohydrate of lime 75·68, water 24·32, the water being more solidified than in ice. Therefore, as quicklime in its perfectly dry state swells from the moisture of the atmosphere, there scarcely needs be any surprise in the mind of a reflecting person, that this would cause to flee, upon change of temperature, vessels whose clay has it as one component. Yet this fact seems to have been overlooked by the Manufacturers in reference to Paris white, and it equally regards the use of bone earth. When much if not all the water of phosphoric acid combined with the lime in bone has been dissipated, only the greatest care can prevent its supplying itself again from the atmosphere, and as the lime itself is, by the baking process, rendered caustic, it will similarly solicit moisture from the same source, each of which causes will soften the ware.

Earth of Bone.—*Phosphate of Lime.*—This, in its prepared state, is a white powder, without odour, caustic savour, insoluble in water, but soluble in nitric, muriatic and acetic acids; precipitable unaltered by test 2, and at a very high temperature fusible into a white enamel. Its general refractory nature, when a component of the cupels employed in metallurgy, may have suggested its employment in soft porcelains, where in addition to its correcting any discoloration from peroxide of iron in the clay, it aids the production of translucence; but I am not aware of the person by whom was made the first bone china.

Scheele first published, but Gahn was first successful in, the analysis of the earth of bones, and

exhibited it as phosphate of lime; and his sagacity is the more entitled to attention, because the native phosphate of lime has proved too difficult for the processes of very celebrated chemists. In p. 68, vol. xxxiv., *Ann. de Chimie*, are the truly interesting researches of Merat Guillot, on the several components of the different kinds of bones, which are presented in a condensed form below:—

Names of the several Substances employed.	Proportions of			
	Gelatine.	Phosphate of Lime.	Carbonate of Lime.	Loss.
Human bones taken from a burial ground, per ct.	16·	67·	1·5	15·5
——— dried, but never interred	23·	63·	2·	2·
Bones of the ox	3·	93·	2·	2·
——— calf	25·	54·	—	21·
——— horse	9·	67·5	1·25	22·25
——— sheep	16·	70·	0·5	13·5
——— elk	1·5	90·	1·	7·5
——— hog	17·	52·	1·	30·
——— hare	9·	85·	1·	5·
——— chicken	6·	72·	1·5	20·5
——— pike	12·	64·	1·	23·
——— carp	6·	45·	0·5	48·5
——— viper	21·5	60·5	0·5	17·5
——— lobster	18·	14·	40·	28·
Teeth of the horse	12·	85·5	0·25	2·25
——— elephant	24·	64·	0·1	11·15
Stags' horns	27·	57·5	1·	14·5
Egg-shell	3·	2·	72·	23·
Mother-of-pearl	2·5	0·	66·	31·5
Crabs'-eyes	2·	12·	60·	26·
Shell of the cuttle-fish	8·	0·	68·	24·
White coral	1·5	0·	50·	48·5
Red ditto	0·5	0·	53·5	46·

Processes.—A solution of muriate of lime treat with solution of phosphate of soda; leave to repose 24 hours; there will be a precipitate of neutral phosphate of lime, 1 P + 1 L + 2 Water. Reverse the details. To the solution of phosphate of soda gradually add muriate of lime; when almost equivalent to the former leave to repose, as before, and the precipitate will be a sub-phosphate of lime, similar in composition to calcined bones as used for introducing into soft porcelain.

PLASTER OF PARIS, *Gypsum, Sulphate of Lime,* is obtained from Chelaston, near Derby, and from Beacon Hill, near Newark, Nottinghamshire. It is without odour or savour, specific gravity 2·31, is soluble in 450° of hot water, and 500° of cold; it is fusible by a moderate heat; is separable by carbonated alkalies, and decomposed by ignition with charcoal. It is prepared for the Manufacturer's purposes—moulds for vessels and figures—by being ground between mill-stones, and afterwards evaporated on a long brick trough, beneath which are flues for the passage of heat from the fire. This process is named *boiling* the plaster, because the escape of the moisture causes decrepitation and effervescence. At 160° Fahrenheit it is completely prepared; and afterwards it most quickly solicits to combination water, or other neutral liquid, becomes hot, and rapidly solidifies.

Mould Making.—Moulds are formed in the following manner: The statue or figure to be copied is first oiled, to prevent it from cohering with the gypsum. A quantity of liquid plaster, sufficient for the mould, is then poured on, immediately after being mixed, and suffered to harden. If the subject be a bas-relief, or any figure which can be withdrawn without injury, the mould may be considered as finished, requiring only to be surrounded with an edging. But if it be a statue, it cannot be withdrawn without breaking the mould, and on this account it becomes necessary to divide the mould into such a number of pieces as will separate perfectly from the original. These are taken off from the statue, and when afterwards replaced, or put together without the statue, they constitute a perfect mould. This mould, its parts having been oiled to prevent adhesion, is made to receive a quantity of plaster, by pouring it in at a small orifice. The mould is then turned in every direction in order that the plaster may fill every part of the surface, and when a sufficient quantity is poured in to produce the strength

required in the cast, the remainder is often left hollow, for the sake of lightness and economy of the material. When the cast is dry it is extricated by separating the pieces of the mould, and finished by removing the seams and blemishes with the proper tools. Casts of plaster are varnished by a mixture of soap and white wax in boiling water. A quarter of an ounce of soap is dissolved in a pint of water, and an equal quantity of wax afterwards incorporated. The cast is dipped in this liquid, and after drying a week is polished by rubbing with soft linen. The surface produced in this manner approaches to the polish of marble. When plaster casts are to be exposed to the weather, their durability is greatly increased by saturating them with linseed-oil, with which wax or rosin may be combined. When intended to resemble bronze, a soap is used, made of linseed-oil and soda, coloured by the sulphates of copper and iron. Walls and ceilings are rendered waterproof in the same way.

If the form or position require it, the limbs are cast separately, and afterwards cemented on. Moulds and busts are obtained in a similar manner from living faces, by covering them with new plaster, and removing it in pieces as it becomes hard. It is necessary that the skin of the face should be oiled, and during the operation the eyes are closed, and the person breathes through tubes inserted in the nostrils. Elastic moulds have been formed by pouring upon the figure to be copied a strong solution of glue. This hardens upon cooling, and takes a fine impression. It is then cut into suitable pieces and removed. The advantage of the elastic mould is that it separates more easily from irregular surfaces, or those with uneven projections and undercuttings, from which a common mould could not be removed without violence.

Glue Moulds for Casting.—The body to be moulded, previously oiled, must be secured one inch above the surface of a board, and then surrounded by a wall of clay distant about an inch from its sides; the clay must also extend rather higher than the contained body; into this warm melted glue, as thick as possible, is to be poured, so as to completely cover the body to be moulded: the glue is to remain till cold, when it will have set into an elastic mass. Having removed the clay, the glue is to be cut into as many pieces as may be necessary for its removal.

MAGNESIA.

MAGNESIA, one of the elementary earths, with a metallic base, *magnesium*, is found native, as a hydrate, a soft white powder, with scarcely any savour, devoid of odour, innocuous compared with lime, is slightly soluble in water, yet with it never forms a ductile adhesive mass; reddens turmeric paper, and changes vegetable blues and violets to a green tint (yet these effects are not produced by the water filtered from the earth itself after agitation therein); is not dissolved by solutions of alkalies or the alkaline earths; has more resemblance to earths than the alkalies; alone it is refractory at the highest temperature, yet with lime and alumine and silica it fuses into a porcellaneous mass; yet not when with barytes or strontia. As a component of some of the rocks which form the crust of the globe, steatite, and serpentine, it is in considerable quantity; and also with lime, in very extensive formations. The perfect separation of these two is an extremely interesting problem in chemical analysis, and because of its difficulty some excellent chemists have supposed magnesia a modification of lime. The magnesian limestone is sooner rendered caustic, at a loss of about 60 per cent., than the other, because this more solicits to combination carbonic acid. The earth itself has been very little employed in the Arts of Life; and although ordinary limestone, certainly of a good quality, has been some time introduced as Paris white, I am not aware that the magnesian limestone has been submitted to trial.

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Process.—In distilled water dissolve sulphate of magnesia (Epsom salts), filter, add test 1, and the precipitate will be pure magnesia; filter out, wash well, evaporate dry, incandesce, and keep in a well-stoppered phial from the air. The sulphate of magnesia, moistened, in the galvanic circuit in contact with mercury, was decomposed into its basic metal, white, much like silver, and with a specific gravity of 1·780.

As alumine solely by many has been supposed the only earth really useful in the fabrication of the best porcelain, there seems the more necessity and propriety in recording the following remarks; and especially as there is a probability that the vicinity of Epsom would supply some of the earth in question, by which the trial could be properly made:—

At Castellamonte, in Italy, and at Baudissero, nine miles from Ivree and Brozzo, in Canavais, Department of the Loire, is quarried a porcelain earth, or clay, compact as the hardest chalk, amorphous, white as ceruse, without argillaceous odour, not adhering to the tongue, so slightly affected by water as not to form a solid paste, yet agglutinates and contracts a little by drying at 350°; specific gravity 2·800. The former, according to Guyton, has magnesia 26·3, silica, 14·2, carb. acid 46, water 12; the latter, according to Bucholz, has magnesia 46·0, carb. acid 51, with a trace of alumine, lime, manganese and water. It is employed with clay in the fabrication of crucibles not affected by the file, and of stone ware; and with silica, in that of very fine porcelain, by Gioannetti, at Vineuf, being regarded as very excellent for that purpose. I should not be much surprised if ultimately it be found that the component of Nankin porcelain,

whose nature and use are so extremely carefully concealed by the Chinese potters, is a magnesian earth, or a silicate of alumine and magnesia.

In 1805, December 22, that eminent chemist, Proust, of Madrid, thus addressed Vauquelin: "We are going to-morrow to see the Manufacture of porcelain, under the direction of M. Sureda, who was brought up to this Art in the manufactory at Sevres, and now *makes a most beautiful porcelain, of a much harder texture than yours. This is not effected by kaolin, but with the spuma maris* [Meerschaum of Werner], a silicious magnesian-stone, found in the neighbourhood of Madrid. We shall send you some specimens which will astonish you. He covers his biscuit with feldspars of Gallicia, which are very beautiful. The stone would be very excellent for the formation of chemical furnaces. When taken from the quarry it is soft, and admits of being cut, like soap. Furnaces made of this stone are extremely light, and never undergo fusion, however high may be raised the temperature. Besides magnesia, silica, and some particles of argil [alumine] and lime, this stone contains a portion of [alkali] potash, which contributes not a little to the superior qualities of the porcelain." The information contained in this letter I regard as very important, when we refer to the time of its being written.

Steatite.—The soapstone, employed in the Swansea China Manufactory, is from Mullyan Churchtown, and from a vein of serpentine near the Lizard Point. It is greenish-white, tinged yellowish sometimes, has a fine earthy texture, unctuous to the touch, soapy lustre, infusible alone before the blow-

pipe. When first quarried, can be kneaded like dough; but after being some time exposed and deprived of part of its moisture, its edges become translucent, though it can be scratched by the nail. silica 44, alumine 10, magnesia 24, water 22.

Having business which brought me to Swansea, in 1831, I visited both Manufactories, and entered into free conversation with several of the artisans. The whole of the china department at Mr. Dilwyn's was discontinued, because the principal himself was disgusted with the frequent failures, and consequent sacrifices of capital, of the person to whom he confided the management, as body and glaze were constantly unsuitable for each other, and *guessing* usually rendered the affair worse. I felt wishful to obtain some of the body *clay* and the fluid glaze for analytic investigation, that I might have suggested the probable cause and also the remedy; I confess, hoping also for a douceur from the principal on the information being communicated. But I failed to obtain them, and my general remarks were similar to speaking to a person in an unknown tongue.

BARYTES.

BARYTES (from *barus*, heavy, a peculiar characteristic of its natural combinations), one of the elementary earths, the oxide or balanced alkali of the metal *Barium* (B 17·5 + 4 Ox.), the most potent (and strontia next) of the alkaline bases. As hydrate, it is extremely poisonous if taken into the stomach; its colour is greyish-white, specific gravity 4; it is without odour; its savour is more harsh and caustic than lime; in its native state it is porous and easily pulverised; with less violence, yet like the fixed alkalies, it corrodes the animal fibre to which it is applied; like lime, it slakes in air, and falls to powder by absorption of moisture; it is soluble 5 per cent. in water, at 60°, and about 50 at 212°; the solution, like the hydrate, possessing the distinctive alkaline potency of rendering vegetable blues and purples of a green tint; as the liquid cools beautiful prismatic crystals form; and by soliciting the carbonic acid of the atmosphere, like lime, there is formed a pellicle on the surface of the liquid. By the rise of temperature it hardens, and has a bluish-green tint. The blow-pipe flame causes it to intumesce in globules, and enter the charcoal support, because of the presence of the water of crystallisation. During fusion the hydrate will combine with several of the earths and metallic oxides, rendering them soluble in acids or in water; and whether alone or with other elements, as reagents, the employment is of great importance for the purposes of scientific illustration by analytical

processes. Thus, either as a nitrate or muriate, exhibited to detect the presence of sulphuric acid, the other acid will appropriate the base, and the earth combined with the sulphuric acid will precipitate as an insoluble powder. The mineral kingdom supplies great plenty of it, combined with sulphuric acid, and less frequently with carbonic acid.

Processes 1 (*Cheapest and Best*).—Mix well of the mineral sulphate in powder 8 parts, muriate of soda 4 parts, charcoal powder 1 part, bring into a state of incandescence, and during one hour keep occasionally stirring the assay. The muriate of soda solicits the oxygen, and thereby facilitates the decomposition. When cool, crush the sulphuret coarsely, add it to 32 parts of water, raise the temperature to 212°, for five minutes, quickly filter, and keep in close phials ready for further processes.

2. The powders of sulphate of barytes and charcoal, 2 and 1, subject to very high temperature four hours (as in the mouth of a fired-up oven); mix well in boiling-water whatever is soluble; filter the liquid, add carbonate of soda, the white precipitate filter out, wash well, again mix with charcoal powder, and incandesce two hours; then again cast into boiling-water, and with paper cover close the vessel; powerful reaction will be manifested; the barytes will be soluble therein, and two new products result, of the crystals, and the liquid; and will, as the temperature falls, form the crystals, which collect for use; and the barytic liquid left can be evaporated, and will present a further supply.

3. Because of the great combinative potency of the earth and the sulphuric acid, only partially affected by the presence of charcoal in high temperatures, and the difficulty of raising to a sufficiently high temperature a mineral, when in company with so sluggish a conductor as charcoal, only does this process succeed at very high temperatures.

4. The powders as above, 4 and 1, incandesce three hours; then dissolve in boiling water, and by a syphon quickly decant the liquid; acidulate with test 25 (or 4. The native carbonate dissolve in test 25); evaporate, crystallise, incandesce the crystals, cover close, cool, and keep in a well-stoppered phial.

5. To obtain test 30. The liquid of process 1 treat with test 26 until no more of test 14 evolves; filter, and wash the filter with distilled water at 212°; then evaporate till a pellicle commences; re-filter, and allow repose to crystallise; separate the crystals; again evaporate the liquid, and the process repeat until all the barytes is obtained; mix all the crystals, and pulverise; add boiling pure water, again evaporate, and select the best crystals for keeping, and the ley preserve as barytic water, to mix with equal quantity of solution of borax for a certain glaze. The test 36 must be obtained by substituting test 25 for 26 as above.

When the hydrate supplied by process 2 is again incandesced, it will (but that by 3 will not) fuse and assume the appearance of oil. We, by igniting crystallised barytes obtain an alkaline earth, protoxide of barium, combined with water (B 17·5 + 4·5 W), concerning which, Berthollet says, "the earth is engaged with a substance which *diminishes* its action on other bodies, which renders it more fusible, and which gives it by fusion the appearance of glass."

Sulphate of Barytes.—Cauk stone, heavy or ponderous spar, is by Nature presented in a variety of beautifully-crystallised forms. It is that very heavy brittle flesh-coloured mineral, with a foliated texture, found plentifully in copper mines, and frequently accompanying galena, or common lead ore, of which it often forms the gangue; supposed to be lime and sulphuric acid, but which Galen first proved is a compound of sulphuric acid and the earth which Scheele discovered; specific gravity 4·5, B 17·5 + 20 s. acid. At 30° Wedgwood, fuses into a white opaque mass.

Sulphate of barytes decrepitates before the blow-pipe, but is not easily fused, which distinguishes it

from sulphate of strontian or of lime. Its particle is 1 atom sulphuric acid + 1 atom barytes.

In Strontian lead mine the common gangue of the galena is a compound of 2 atoms sulphate of lime and 5 atoms sulphate of barytes ; and in Yorkshire, between Leeds and Harrowgate, is a species of 9 atoms sulphate of lime + 2 atoms sulphate of barytes.

Carbonate of Barytes.—Rats stone, Witherite, is greyish-white, semi-translucent, glistening, bladed or fibrous in structure, frequently with small cavities lined with minute crystals ; specific gravity 4·3, B 17·5 + 11 carbonic acid.

There is a species compounded of 1 atom of sulphate of barytes + 2 atoms carbonate of barytes.

The crystals of carbonate of barytes are small and semi-transparent ; the massive varieties are only translucent. Before the blow-pipe it fuses readily into a clear glass, which in cooling becomes a white enamel. On charcoal it effervesces much, becomes caustic, and then sinks into the support. With borax and phosphate of soda it melts into a clear glass, which becomes opaque and white on cooling, when the quantity of the carbonate of barytes is proportionate to that of the fluxes.

FELSPAR.

FELSPAR is the generic name of the mineral, which in its species is next to quartz most generally diffused in the crust of the globe. Its colours vary in the species from grey-white, brown, yellow, and verdigris-green; inferior to quartz in hardness, yet not scratched by the knife; specific gravity 2·6; with vitreous lustre; in the American species recently introduced, crystallised; in those of Middletown Hill, Montgomeryshire, broad foliated (best for glaze) masses, rarely granular (best), occasionally quite compact (for body); in the blow-pipe flame, on charcoal support, semi-transparent white vitreous assay, but only at a very high temperature do the edges fuse into a semi-transparent vesicular glass.

Though felspar is one component with quartz and mica of the granite, it must be understood that the hardness of this conglomerate will greatly depend on the species of felspar, hereafter noticed, as containing the least alkali.* Often is the felspar found in concrete masses separately from the other components of granite, forming irregular beds of varying extent. Of the difference in the nature of its species, an idea may be formed from the annexed weights of the stone in cubic feet and inches :—

* Ignorance of this peculiarity has caused the rejection of excellent grauen by persons who trusted to guesses. Even a few days before this sheet went to press, a person (who manages one of the Manufactories belonging to the gentlemen who own my residence) showed me a large quantity of excellent grauen, when properly treated, but which had till then been employed merely to form the sides and butments of the flint-kilns at the Greenfield Mill.

		Cubic Foot.		Inches.
China	2385	149·1		0·086
Siberia	2368	145·3		0·085
Salberg	2229	140·1		0·079
Passau	2290	143·4		0·080
Bayonne	2312	144·5		0·082
Limoges	2341	146·4		0·084
Sevres	2146	134·1		0·077
Middletown Hill	2370	147·2		0·085

The components of these varieties are equally different in analysis. A crystallised specimen, from Stella, a part of St. Gothard, by Vauquelin, and the other kinds mentioned, supply the following :—

	Crystal. Vauquelin.	Green. Rose	Fl. Red. Buchoby.	Passau. Godon.	Salberg. Vauq.	Uton. white.	Middletown Hill. b. gr.	green.
Silica	64·0	63·0	67·0	62·5	68·0	64·5	60·0	64·0	68·0
Alumine	20·0	18·0	17·0	22·0	20·0	24·5	22·0	24·0	20·0
Alkali (Lithia)	14·0	14·0	14·5	14·0	11·0	8·0	16·0	10·0	10·0
Lime	2·0	3·0	1·5	·75	1·0	3·0	2·0	2·0	2·0
Spiced with Iron oxide									
	100·0	98·0	100·0	99·25	100·0	100·0	100·0	100·0	100·0

The correspondence of several of these to the principle assumed at page 48 must occur to every attentive reader of this work, and will render obvious the real cause of the difference in the two kinds of felspar for the Manufacture. In the white the greater dose of alkali increases its fusible property; in the green the extra dose of silica renders it more refractory; and in the intermediate kind the components are in their natural proportions, in round numbers: Silica 15 × 4 + Alumine 6 × 4 + Lithia 4 × 4 = 100; Silica 16 × 4 + Alumine 6 × 4 + Lithia 3 × 4 = 100; Silica 17 × 4 + Alumine 6 × 4 + Lithia 2 × 4 = 100. The regularity of Silica and Alumine is very remarkable; but the irregularity of

the alkali (however we call it potash, lithia, lime or oxide of iron ; as many of the analyses made prior to Arfwerdson's determining that it was the *stone* alkali), induces an opinion, that galvanic agency, not yet developed, operates on the principle of the mineral, and causes the result mistaken for lime. Certainly so minute a proportion of this earth, and not in the regular quantity of its combinative potency, does warrant the belief that some unknown cause is here in operation.

The lamp of chemistry sheds an effulgence on the peculiarities of minerals in analysis exhibiting the presence and excess of useful or deleterious components, not supplied by descriptive characters. And the information is absolutely needful to the intelligent Manufacturer, no longer as a matter of conjecture. This will always determine the relation of minerals. The petalite of Sweden and that of Dublin differ very little, if my analysis and those of Arfwerdson and Gmelin be correct. Not but that I fear that one has more than the proper quantity of silica. And I feel gratified with the approximation of the second to the general principle of this work. Indeed, the more I notice analyses, the more am I attached to the hypothesis.

	Arfwerdson.	Gmelin.	Dublin specimen.
Silica	79·212	74·17	72·18
Alumine	17·225	17·41	18·28
Lithia	5·761	5·16	6·10
Lime		0·32	1·14
Water		2·17	2·20
Loss		·77	·5
			100·40

Processes (1.)—In a silver crucible put 10 grains of felspar powder and 40 grains of hydrate of potash, also in powder; fuse them together fifteen minutes. *a.* Add test 26, and with glass cane stir till all is dissolved, then decant into a capsule and evaporate dry; again dissolve in test 26, and filter out the silica; wash well, dry, ignite, and weigh (about 6·5 grains, or 64 per cent.). *b.* The washings add to the aciduline liquid; alkalinise by test 2, the precipitate filter out, wash well, evaporate, and dry. *c.* The liquid and washings evaporate to a fourth, add test 3, filter out the precipitate, wash, dry, ignite, and weigh the lime (after deducting the carbonic acid), 1·25. *d.* The precipitate *b.* dissolve in test 26, alkalinise with test 1, raise to 212° fifteen minutes, and filter out any spice of iron. *e.* To the liquid add test 34; the precipitate filter out, wash well, evaporate dry, and incandesce the alumine, 2·5, or 24. The alkali find by another process.

(2.) (*Lowitz.*)—Put into a silver crucible powders of carbonate of potash 50 grains, carbonate of soda 4, and felspar 30; while raising the temperature carefully stir to prevent loss by the ebullition; fuse fifteen minutes; then add 1 ounce of boiling pure water; filter out the silica, wash well, incandesce, and weigh. The liquid evaporate much, and find the alumine, etc., as before.

For the Alkali; the Lithia.—In the silver crucible (with a leaden head, and a leaden pipe and receiver adapted for refrigeration) put powder of fluor spar 2, and felspar 1; the temperature gradually raise, and let the gas evolve, and carry over all silicic acid. In hot water dissolve the sulphate of lithia, and pass the liquid very hot through the filter, on which will remain the alumine and other earths and oxides present. The filtered liquid evaporate dry, and weigh the product.

The petalite is Al. 3 + Sil. 4 + L. 1 + S. 3 = 22·25; so that it is a compound of silicate of alumine and silicate of lithia.

Grauen (*or China Stone*).

This remarkable kind of granite is found only in Cornwall, and mostly in the vicinity of St. Stephens, a few miles from St. Austle. The rock has the three components, small transparent crystals of quartz, disintegrated white and soft common felspar, and small scales of mica, mechanically mixed, and without any spice of metal whatever in the best kinds.*

The grauen of Cornwall, as likewise the clay from its decomposed masses (hereafter mentioned), were first introduced into the Manufacture by Mr. Cookworthy, a relative of my wife's maternal ancestors. He had closely considered the properties

* The several kinds of granite have solubility precisely in the ratio of the quantity or proportions and quality of the felspar from plus or minus of lithia; as this is assisted in its separative potency by the white oxide of iron in the mica, and the carbonic acid of the air, and the oxygen of the water. This is the mean of the components, and also their respective analysis, in 300 grains :—

	Quartz.	Felspar.	Mica.
Silica	96	64·	48
Alumine	2	20·	24
Lime	2	1·75	—
Potass	—	—	11·5
Oxide of Iron	—	·25	15
Lithia	—	14·	—
Manganese	—	—	1·5
	100·0	100·00	100·0

of the specimens sent from China by D'Entrecolles, and obtained from Limoges by Réaumur, and while residing at Plymouth he made the needful experiments on the grauen, and obtained a patent for its appropriation; which patent he sold to Mr. Richard Champion, of Bristol, son of the spirited Mr. C. who erected the first laboratory for the reduction of zinc, under a patent, in 1743 as Dr. Ure incidentally mentions, *Dict. Chem.*, p. 671, 4th edition.

There is some difference in the grauen from different quarries in regard to the precise proportions of the components, quartz, felspar and mica, though always resolvable into the chemical components, silica alumine and alkali. Sometimes the rock resembles an earth, is easily pulverised, and, breathed on, supplies the odour of clay; in other instances it is undurated, and does easily yield to the action of air and moisture. The crystallised quartz, merely silica with a spice of alumine, varies in its proportions, and is not needed in either body or glaze, because its silica can be supplied by flint; and also, although it is resistive of disintegration by the atmosphere, yet every crystalline substance constantly tends on every presented opportunity to resume its crystal form, the momentum of the tendency being varied by the menstruum, quantity, and combinative potency of the elements. The mica likewise varies in its proportions, and much deteriorates the other components, injuring proportionately the ware into whose body it is introduced. Whenever its phosphoric acid is solicited by sulphuric acid, the combination effects the glaze, and causes it to be without lustre, richness or permanence. The felspar is very

well adapted to the purposes of the Art, and especially when these are combined with determined proportions of other components. Hence the difference in the purchased ground-stone, and also in the china clays supplied to the Manufacturers.

Each of the works has a quarry for the grauen, which is first detached by blasting and wedges, and then broken into pieces of suitable size to be forwarded for the Manufacturer. A little inspection will prove that in this rock much felspar is present in a disintegrated state, not seldom with a slight proportion of magnesite or steatite. The stone thus quarried is not subjected to any further process or preparation prior to being shipped at Charlestown or Portsea.*

* In Nicholson's *Philosophical Journal*, vol. viii., pp. 127-131, is Mr. Accum's Analysis of Grauen, which, because the details are curious, I did intend to introduce; but on examining them I found, and I think so will every other person who understands what he reads, find (that, although I do not mean to charge Mr. A. with excessive modesty in assertion, nor over-scrupulousness in conclusions) the results he gives as the components will not accord with those of any of the analysts now acknowledged. He has overlooked the composition of the grauen—quartz, felspar and mica; he has forgotten that lime is ever present in the second, and also with fluoric acid in the last; in exper. xii. he obtains 9 grs. of *muriate of soda*, which in xiii. supply him with 4·50 grs. of *potash;* and the whole contains, in 100 grs., silica 60·00, alumine 28·00, oxide of iron 0·25, potash 4·50, water 6·00, Loss 1·25 = 100. How Mr. Nicholson overlooked the statement, we need not inquire.

CHINA CLAY.

When the atmospheric alternations cause the grauen to disintegrate wholly, the felspar crumbles to powder, and the result is the China Clay—an indispensable component of the body of porcelain and best earthenware, because of the entire absence of metallic particles. When properly prepared, usually it has a beautiful and uniform milk whiteness, and breaks readily between the fingers, without grittiness. However soft and white the several kinds may appear, they are not pure alumine, but native neutralised compounds of silicic acid and alumine. That remark of Wedgwood's, that the components are alumine 60, silica 20, and adventitious substances and loss 20, must have been an oversight; for as the crude grauen has silica 208, alumine 44, lime 4, and alkali 44, in 300, there seems no way by which the atmospheric action can abstract 148 of the chief component silica, and introduce 136 of the alumine, and yet without altering the other components. The proportions of the porcelain earths of the continent support the view I have taken of the china clay. That of Limoges, used for the porcelain of Sevres, and also exported to Copenhagen for the like purpose, has silica 65, alumine 35; that of Passau, used at Vienna, silica 70, alumine 30; and that of Aux, used at both Dresden and Berlin, silica 69, alumine 31; though H. Rose gives 52 and 47 as the mean of all the kinds. The Chinese porcelain earth, or kaolin, when pure, is friable, meagre to

the touch, scarcely adheres to the tongue, and with difficulty forms a paste with water, and is refractory in the oven.

The clay, as found native, resembles new-made mortar in colour and general appearance. Many angular fragments dispersed in it prove that it has not been far conveyed. Also reddish-brown irregular stripes, patches and veins occur, and because of the mica present, are separated, as *weed*, by the workmen. There probably is plenty of the clay in other parts of Cornwall, but the ports of Liverpool and Bristol, and the potteries of Staffordshire and the North, are supplied from several works in a barren district a few miles from St. Austle.

The clay is found at various depths below the surface from 2 to 20 feet, over which are superimposed, separated by a waving irregular outline, a bed of light-coloured earth, and over this the vegetable soil. In some beds the clay *holds down* 30 feet or more, at Trethosa. Being found in valleys or ravines, it is regarded as having been many ages depositing from the detritus of the grauen by the water from the ground above. The clay is dug in progressive roads, 4 or 5 feet deep, and either cast in a large heap, or immediately conveyed to the spot to be in small heaps on a large scale *elutriated*. In the vicinity of the works is a stream of water, which is caused to flow over these small heaps, which are frequently turned by mechanical and manual agency. In passing through and over the heap, the water becomes charged with particles of clay, and passes by proper arrangements into tanks of different sizes, provided with plug-boards, like the arks of our

flint-mills. The first is called the mica pit, because in it the most ponderous and useless particles subside; while the lighter particles are carried away into other tanks, where deposition is carried on further; and the water from the pits ultimately is received into more capacious tanks, in which only the finest particles deposit. When a certain quantity of deposit is supplied, and the clear water drained away, the clay, like a thick mud, is spread over shallow tanks called *pans*, 10 or 14 inches thick, and here it evaporates dry in a few months, the supplies of September being dry in April or May, according to the season and the weather, as also the consistence and thickness of the fluid mass. And probably this long exposure in a moist state renders the clay more fit for the Manufacture, atmospheric changes promoting the decomposition of the felspar. The clay is next cut into brick-shaped blocks, which are either removed to a drying-shed, and placed on wooden bars to freely admit the access of air, or on beds of coarse gravel, as opportunity is presented. When quite dry all the coarser particles, and other injurious appendages, are carefully scraped away, and the fine portion is put and pounded into casks, to fill them completely, in which state they are forwarded to their ulterior destination.

Bleaching Clay.—The scrapings of the dried lumps, and the waste of the packing, are washed in a small pit, near the packing-house, and therein remains all the coarser matters, while the overflow runs into one of the large ponds; whence the water afterwards is carried away by channels beneath,

which in some instances lead to shafts communicating with mine-adits in the rock beneath.

The relative extent of the parts varies at different works. The chief and only erections are a shed for the office, a store-room for the casks, etc., in which the clay is packed, and the others, open on three sides, for drying the clay, formed of timber. At one large Work three small streams wash the clay, and pass in succession, each through three pits, 40 inches deep, two of them 6 feet square, the other 9 feet by 6 feet, the last only supplying the liquid for the nine ponds of various sizes, whence it is laded into sixteen others, for final evaporation. They all are together in a yard. Thirteen persons are here employed; eight to quarry the clay, at a certain price per cubic fathom, three to forward the washing, and two to attend the ponds, pans, and packing, as each might especially need.

Dr. T. Thomson gives this series of analyses of kaolin, or porcelain clay.—(*Mineralogy*, p. 200):—

	Rose.	Berthier.				Thomson.	
		1.	2.	3.	4.	5.	
Silica	52·00	46·8	58·6	55·8	63·5	50·	37·10
Alumine	47·00	37·3	34·6	26·0	28·0	25·	24·48
Alkali	—	2·5	2·4	8·2	1·0	2·0	—
Magnesia	—	—	1·8	0·5	8·0	0·7	—
Lime	—	—	—	—	—	5·5	9·28
Oxide of Iron	0·33	—	—	1·8	—	8·5	6·98
Water	—	13·0	—	7·2	—	9·5	19·22
	99·33	99·6	97·4	99·5	100·5	101·4	97·06

1 from St. Yrieix, 2 Meissen, 3 St. Tropez, 4 Mende, 5 Normandy. He thinks the kaolin is (4 Al. + f.) S. + (Cal. + k.) S. ; or,

Thomson gives these for Arfwerdson and Gmelin:—

Silica	79·212	74·17	Silica	37·08	12·6 atoms.
Alumine	17·225	17·41	Alumine	7·73	2·62
Lithia	5·761	5·16	Lithia	2·94	1·—
Lime		0·32			
Water		2·17			
	102·198	99·23			

We find the atoms of silica (in leetite) rather more than five times as numerous as those of the bases (silica 39·75 atoms, alumine 5·42, soda 1·50, magnesia 0·44, oxide of iron 0·10). If the oxide of Iron be a spice, and we add together the Magnesia and soda, then the atoms of alumine are nearly thrice the number.

CHERT.

This mineral is employed in the flint mills, and the supplies are from Derbyshire and the Halken mountain, in North Wales. The components are as hereafter stated ; but the latter is considered as much better adapted for the purpose, because of the greater quantity of lime present in the former kind, and which becomes intermixed with the flint during the abrasion, and in such proportion increases the liability of the body to be injuriously affected by baking.

The lustre of chert is vitreous, inclining to pearly upon the faces of cleavage, in the varieties possessing pale colours. Colour, various shades of green, often inclining to brown, white, and black, with every intermediate shade; nearly transparent in some varieties, in others opaque; brittle; hardness about the same with feldspar; specific gravity 2·575, 2·620, 2·600.

The analyses supplied from three kinds gave these as the mean results:—

	Halken.	Derbyshire.	
Silex	60·31	58·26	62·38
Alumine	10·26	11·48	12·18
Lime	13·66	13·96	18·20
Magnesia	13·04	2·98	0·00
Protoxide of iron	0·45	3·43	6·04
Ditto Manganese	0·25	7·25	0·10
Fluoric Acid	0·94	1·60	·06
Water and Loss	1·10	1·04	1·04
	100·00	100·00	100·00

CHAPTER V.

METALS.

From the earliest period of recorded time Metals have been the favourite subjects of the chemist's investigation, and during a long era knowledge of their plainest characteristics constituted all implied by the word Chemistry.* And the favouritism is warranted by their great importance and utility, as well as their intimate connection with the Arts and state of civilised society ; their susceptibility of expansion by the hammer or rollers, of extension as wire, of casting into figures, and some

* At page 476 of the *Transactions of the Imperial Academy of Sciences of St. Petersburg*, for 1810, Julius Von Klaproth states, that the cultivation of Chemistry at a very early date by the Chinese is proved by a volume which he describes, written about 756 A.D. In this the principle which we name oxygen is called the impure part of the air, and is supposed to be a combination of sulphur, charcoal, and the metals ; that it may be obtained from saltpetre by the application of high temperature, also from the black stone called Hhetann-ché, and there are conjectures that it is one of the components of water. Respecting the metals the notions have great similarity to those of the alchemists.

not thus tractile form the bases of the artist's palette. Without bronze or steel for cutting instruments, how imperfect would be the state of the Arts, and in similar condition the transactions of commerce without gold or silver as a valuable medium!

From remote antiquity have been known these *seven* Metals—Gold, Silver, Copper, Tin, Iron, Lead, and Mercury, with which every European has some acquaintance; and when first known by the early societies of mankind, such importance was attached to the advantages of their fabrication into utensils or implements, that mythology assigned among the gods the eternal condition of the first practisers of metallurgical chemistry. Our day, however, witnesses the established existence, beyond the possibility of subsequent researches to annihilate, of *six times seven*, allowing that some are mere curiosities of the laboratory, also for the peculiar evanescence of some, and the imperfect current investigation of others.

The usual state in which metals are presented is not the natural one, but the artificial result of the manipulations of art, and the igneous processes of the decomposition of their original compound ores. For we find always, on a scale larger or smaller, from circumstances there is some contrivance or other to keep up a supply of oxygen gas to the mineral, which being fixed by the hydrogen evolved by the fuel, its atomic momenta are transferred to the ore which is to be swelled and deoxydated, while any lime present with the ore melts and combines with the argillaceous substance of the matrix.

The generality of intelligent miners are of opinion *that* ORES GROW, and the certain manner of their growth is proved by numerous and conclusive phenomena. And now that clearer knowledge of chemical agency is current, we may indulge the opinion, that attention to the several conditions will soon develop the connection between the primary principles, the rocks, the matrices, the mineralisers and the resulting metal.

Continuous galvanic action and reaction among the rocks of mines—or the reciprocal action of the principles of acidity and alkalinity with atmospheric air on the rocks, excited by the constant pressure of that active central force ceaselessly produced by the earth's twofold motions—has been demonstrated by experiments made by Mr. Robert Ware Fox, in the mine of Huel Servel, Cornwall. These galvanic momenta must in all instances be regarded as the mere play of oxygen and nitrogen disturbed by different surfaces, and exhibited by the different capability of rocks to conduct the motions of heat and of chemical combination.

The most usual repositories of ores are those stratified portions of mountainous districts by some powerful subterranean agency convulsed and thrown into dislocated masses. In these masses of rocks, near or remote, were caused fissures, cracks, crevices, cavities, and spaces, some almost horizontal, as in extended plains, where exist *beds*, comparatively level, even though at a considerable depth beneath the surface; others with varied dip or inclination; yet often the excavations show that the derangement in the strata has exposed some to the operations of

mechanical agency, which but for that would have been too deeply lodged to have been reached by human art. The fissures in these strata, or fractures and dislocations, when filled with metallic ores are called *Veins*, and not seldom do they separate and again unite, or disperse into ramifications called strings or threads. The vein is usually filled with quartz, calcareous spar, clay, or earth, and because these keep the rocks separate from the metallic ore they are called the matrix, gangue, vein-stone, or rider of the ore, which often runs parallel to the strata, though without any regularity of thickness, and sometimes crosses from the one portion of the rock to the other in all directions. When the vein is not filled up with matrix the crystallised ore lines the cavity. The ore is mineralised, or in a state of combination with sulphur, arsenic, and carbonic acid, the most usual mineralisers, saline compounds; and though not included amongst them, oxygen as frequently as any, the ores being distinguished as sulphurets, arseniates, carbonates, salts, and oxides. The presence of sulphur is demonstrated by the suffocating effluvium resulting when lightning strikes a house, but that of arsenic remains a problem to be solved. From these substances the ores can be separated only by art, though occasionally the metals are exhibited in a native or pure metallic state.

The confusion of rocks in all metallic mining districts, and the extended knowledge current concerning the nature of electric action, suggest this as the most general and probable principle, that all metals are the chemical products of galvanic phenomena. And although this would be regulated by

the proportion of the electric excitement, yet as the age of the metalliferous strata may be a thousand or more centuries, very small increments annually would account for the greatest quantity known of metals. We are well aware of the facts, yet remain uncertain of the manner, in which the combinative potencies of certain modifications of matter generate varied momenta of heat—the principle of galvanic action ; or, the presence of oxygen with other modifications form the several substances named acid, alkali, earth, and oxide ; or, the air in the veins of rocks supplies the elements of electric action ; or, the oxygen and hydrogen principles are carried to the surfaces of rocks ;* or, the outer coating of the vein, the matrix of the ore, whether intermixed or alternating in layers with the ore, is of finer grain than the rocks adjacent ; or, the mineralisers by combination deprive metallic substances of their usual characteristics ; but to this plain acknowledg-

* The alkaline property of metals, and the connection of the principle of alkalinity with hydrogen, have yet to be more clearly explained ; and in the absence of these it will remain matter of conjecture whether or not hydrogen, which constantly solicits and is solicited by oxygen, is essentially metallic—that principle of which every kind of metallic substance is merely a modification—and the *mother-metal* sought by the alchemists, which they only required to discover, and develop the application, to have accomplished their avowed object of transmutation. The race is not yet extinct; for the List of Patents for February, 1836, has this notice : "Lightly Simpson, Manchester, Lancashire, *Alchymist ;* for certain improvements in the preparation of certain colours, etc." The probability, however, is, that Mr. S. is a very clever practitioner of the Art of chemical combination, and desirous to serve society and himself at one and the same time.

ment, as well as to our not having clearly determined other obscure conditions, no more censure will attach than could with propriety be cast on the following truly modest confession of one of the most intelligent metallurgical chemists that has appeared on the stage of philosophical investigation, Professor PROUST, of Madrid. Having been most busily employed in some interesting researches, which he was communicating to the Institute at Paris, after particularising various remarkable phenomena, he says: "In an instant the substances begin to grow red at the points where the heat exerts its action. Is it sulphuretted hydrogen which they lose? *For my part*, I CANNOT TELL."

Agreeably to the character of the oxygen and hydrogen principles, during periods of time extended beyond all chronological data, as already hinted, the silent action of undisturbed galvanism, carrying from surface to surface the aura, or finest particles of the rocks, could not fail to produce intermediate substances—the matrix, the mineraliser, and the metallic particles in threads or ores, with similarity of crystallisation, and every indication of simultaneous generation — filling the intermediate space with compounds of oxygen, nitrogen, and elements of the rocks, whose distinctive qualities would characterise the condition of the produced ore.

Metals are much the greater number of the substances which current processes have failed to prove compounds, or decompose. From their general chemical analogies it was conjectured by the early chemists that they all were, in fact, aggregations in varied proportions of a very few elements; whence

originated the idea of *Transmutation*—the attempt to solve the problem of changing metals of less value into others of greater by altering the proportional quantities of their known as well as of their conjectured elements.* That metals are such compounds

* Perhaps the latest recorded instance of expert juggling in this mysterious and fallacious art, and proof of the practices of alchemy in the east, even in the present century, is the following, given on the authority of an Englishman of talent and respectability: In 1814, over the English Factory at Bassora Mr. Colquhoun was president, and once received the solicitation of an Arabian philosopher for a private interview, to communicate a most important secret. Consent being given, the next morning witnessed the strange and mysterious visitor embracing the president's knees, and supplicating protection from the English against the continued and cruel persecutions of his countrymen, who daily put him to the torture, to wring from him his secret of the method of transmuting the basest metal into gold. He stated that he had just escaped from Grane, where he had been imprisoned and starved by the Sheik, and that on condition of his being permitted to reside in the factory he would faithfully divulge the whole of his knowledge of the processes; and to previously afford a convincing proof of his skill, on Mr. C. expressing a disposition to protect him, he retired for a short time, and then returned to Mr. C., bringing with him a small crucible and chafing-dish of coals. While the former was acquiring a red heat, he took from his pouch four small papers of a whitish powder, and requested some lead from Mr. C. This gentleman retired to his library, and procured four pistol-balls, whose weight he ascertained unknown to the adept. On these and the powders being projected into the crucible fusion immediately ensued, and after 20 minutes the crucible was removed by Mr. C., and when cold, the button in the bottom proved to be of pure gold, and the like weight as the bullets, and in the bazaar was valued at 90 piastres. How the deception was effected—as after the Arab placed the crucible on the coals only Mr. C. touched it—or why a poor Arab should present an Englishman with 90 piastres, cannot be

will seem extremely probable, on the following account: those which are inflammable assuredly must have hydrogen present; whatever inflames cannot be an element; for this phenomenon proves that hydrogen evolves, and combining with oxygen causes burning; therefore, whether or not directly exhibited, there must be present hydrogen, oxygen, and some base, although this last had not yet been developed. All metals by heat vitrify, and vitrification is attributed to silica; hence the probability that silica is also present with such base. In the fracture of iron-stone no metallic particles are visible; it therefore is no less rational to regard the metal as formed of primitive atoms, even though we are ignorant of their nature, than that it is an oxide of what never existed in a native state to be oxidated. Yet, as they remain undecomposed by the solicitings of the most powerful agents, their change, one into another, is a problem whose solution by any train of reasoning is entirely hopeless, and by accident alone will it be developed.

An extended and better acquaintance with combinative potency proves that Davy's decomposition of the alkaline oxides is a mere excitement, promoted and facilitated by the oxygen of the positive pole and the nitrogen of the negative; the

easily determined. However, his return next morning, to enjoy the protection of the factory, agreeably to Mr. C.'s arrangement, was prevented by the Shiek of Grane's armed bands entering the Arab's house during the night, carrying him away, and putting him on board a boat, which was out of sight long before daylight.

disturbance of the former by mere reaction carrying the metal to the negative pole, the oxygen being expelled from the oxides by the atomic momenta and double action of the galvanic poles, on the same principle, that to produce our purified and artificial metals we dissipate the oxygen and nitrogen, disperse the heterogeneous substances, and melt the rocky materials. But the supply of momenta being only temporary and dispersive, and the alkaline base not being adapted for our oxidated atmosphere, whenever opportunity offers the supply is re-absorbed, and the patient becomes an oxide capable again of enduring the atmosphere.

The imperfection of current processes precludes the determination whether, or how far, metals in their metallic state reciprocally solicit each other, and thereby so alter some of their peculiarities as to prevent the usual methods detecting the presence of one or more of them. But if such momenta really exist, and combine substances, two or several, and so blend their properties that together they seem only one, whenever they have fully operated, the sepation into elements will not be an easy task; and more particularly when none of the substances are distinguished for great combinative potency with others. The solution of the problem is an object of much importance, and will be regarded as of comprehensive interest, because it involves a controversy concerning the existence of several substances with which our present imperfect knowledge overburdens us, and compels us to regard as simple, and dignify with the distinction of *elements*.

Of the importance of these discoveries, in

reference to the chemical nature of substances, especially of the metals, no doubt will be entertained, I think, by any reflecting person. And that we are on the eve of yet more interesting developments will be readily admitted by every person who considers the annexed details. In the autumn of 1835 the Academy of Sciences at Paris announced that M. Becquerel has supplied an electro-chemical apparatus of iron, with which, and a concentrated solution of common salt, also the mineral properly prepared, he has effected the immediate reduction of silver, lead, and copper in a crystalline form, and in a regular succession, but with varied facility, because of their different degrees of oxidation, and of the compounds generated during their deoxidation. M. Aimé has improved the apparatus. An open tube of iron is bent in the form of U ; the outer portion at the bottom of the bend is pierced with a small hole, into which is loosely put a little asbestos. The legs are half-filled with fine, well-washed sand, and afterwards one is filled with dilute sulphuric acid, and the other with a concentrated solution of sea-salt (in such a state of non-equivalence, however, as will preclude the formation, on their combining, of a salt, which would obstruct the discharge), also by arrangements for a supply regulated by the proportionate discharge after their combination, thereby securing an indefinite continuance of the decomposing process, varied in its intensity by the concentration of the solutions, and the facility of the combination consequent on the size of the orifice for the discharge. The two fluids permeate the sand, and combine at the lower part of the tube, forming a

fluid which escapes through the hole. Into each leg dips a platinum slip, from each of which extends a wire to a galvanometer. On forming the circuit by contact, the change of direction of the needle indicates the formation of the momenta resulting from the reciprocal action of the fluids.

Reasoning from the phenomena of potassium, sodium, lithium, barium, strontium, calcium, and magnesium (the metals obtained by galvanic reduction of their oxides, potash, soda, lithia, barytes, strontia, lime and magnesia), metals are alkalies, combined with sufficient oxygen, not to neutralise the alkaline bases, but to protect them, and counteract the prevalent tendency to become oxides in the ordinary state of the atmosphere. Like sufficiency of oxygen, in varied degrees, affects other metals; but it is obvious that all of them equally consist of oxygen and an alkaline base, not yet known definitively as simple or compounded, though the varied colours of the oxides, and their re-active potencies, imply some combination with the alkali. These six metals—aluminum, glucinum, cerium, yttrium, zirconium and thorium, are formed by abstracting oxygen from their earths (which as pure oxides are white inodourous powders), and which seem probably compounds of carbon with other elements.

With the exception of two or three metals—harder than the others probably from excess of a silicious base over the alkali combined during their electrical generation—all the metals, from the evanescent potassium to the one most fixed, agreeably to the variety of their components, have every degree of tendency to abstract the oxygen

of the air, and, as oxides, return to their original state.

The Metals possess the following general CHARACTERISTICS: 1. A peculiar lustre, continued in the fractured streak and smallest fragments. 2. Fusibility by heat, and while fused retaining their lustre and opacity. 3. Ready concentration of the motions of heat, and of oxygen separated from hydrogen by the electric machine and the galvanic circuit. 4. Being malleable, laminable, and ductile, extending under the hammer, by the rolling-press, or through the wire-mill; the susceptibility resulting from a tenacity peculiar to each kind, yet different in degree. 5. Brilliance and opacity, reflecting most of the rays of light which fall on their surface; hence forming excellent mirrors. 6. When in fusion susceptible of combining with each other, in metallic alloys, in determined proportions, yet preserving peculiar lustre and tenacity. 7. In the galvanic circuit their saline compounds are decomposed, the negative pole soliciting the respective metals. 8. At a high temperature, in presence of oxygen, chlorine, and iodine, most of them inflame; and, combining with one or other of the three in determined proportions, they form bodies devoid of ductility and lustre, but saline-looking or earthy, termed oxides chlorides, and iodides. 9. Most of them combine, in determined proportions, with sulphur and phosphorus, forming semi-metallic compounds. Others, to form peculiar gaseous or solid compounds, combine with hydrogen, carbon, and boron. 10. Many of them, by certain processes, crystallise mostly in cubes or octahedrons.

NAMES.	Specific Gravity.	COLOUR.	Malleable or Brittle.	Tenacity.	Fusibility. Fahr.	Fusibility. Wedgwood.	PRECIPITANTS. Sulphuret of Lime.	COLOUR OF PRECIPITATES BY Ferrocyanate prussiate of Potash.	Infusion of Galls.	Hydrosulphurets.	Sulpd. Hydrogen.	Hydriodate of Zinc.
Platinum	21·47	White	M	274·31	...	170+	Muriate of amm.	.....	.....	.....	Black met. powder	Deep brownish-rd
Gold	19·30	Yellow	M	150·7	...	32	Sulph. iron / Nitrate mercury	Yellowish-white	Green, metallic	Yellow	Black met. powder / Yellow	Dirty-orange / Yellow-white
Silver	10·45	White	M	187 13	...	22	Common salt	White	Yellowish-brown	Black	Black	
Palladium	11·8	White	M	.	...	170+	Prussiate of mercury	Deep orange	.....	Blackish-brown	Black-brown	
Mercury	13·6	White	M	...	39	...	Common salt, Heat	Yellowish-white	Orange-yellow	Brownish-black	Black	
Copper	8·9	Red	M	302·26	...	27	Iron	Red-brown	Brown	Black	Black	Greenish-cream
Iron	7·7	Grey	M	549·25	...	158°	Succinate soda, with peroxide	Blue, bluish-white	Peroxide, black	Black	Black	..... / .....
Tin	7·29	White	M	34·7	442	...	(Perchloride of Mercury)	White	.....	Proto & peroxide	Brown / Yellow	Bright-lemon / Black
Lead	11·35	Blue	M	27·7	612°	...	Sulphate of soda	White	White	Black	Black	
Nickel	8·4	White	M	...	...	160+	Sulphate of potash	White	Grey-white	Black	Black	
Cadmium	8·6	White	M	...	...	...	Zinc	White	.....	White	Yellowish-white	.....
Zinc	6·9	White	M	109·8	680°	...	Alkaline carbonates	White	.....	White	Yellowish-white	.....
Bismuth	9·88	Cream	B	20·1	476	...	Water	White	Yellow	Black-brown	Black-brown	
Antimony	6·70	White	B	...	810	...	Water and zinc	White dilute solutions	White	Orange	Orange	
Manganese	8·0	Grey	B	...	...	160	Tartrate of potash	White	White	White	Milkiness	
Cobalt	8·6	Grey	B	...	...	130	Alkaline carbonates	Brown-yellow	Yellow-white	Black	Milkiness	Rhubarb
Tellurium	6·115	White	B	...	...	...	Water and antimony	.....	Yellow	Blackish		
Arsenic	8·35 / 5·76	Bluish-wh.	B	...	...	...	Nitrate of lead	White	.....	Yellow	Yellow	.....
Chromium	5·90	White	B	...	...	170+	Nitrate of lead	Green	Brown	Green		
Molybdenum	8·6	White	B	...	...	170+	Ditto	Brown	Deep brown	.....	Brown	
Tungsten	17·4	White	B	...	...	170+	Muriate of lime?	.....	.....	.....		
Columbium	5·6	Grey	B	...	...	170+	Zinc	Olive	Orange	Chocolate		
Selenium	4·3	Blue	B	...	220	...	Iron / Sulphate of amm.	.....	.....			
Osmium	?	Dark grey	M	...	...	...	Mercury	.....	Purple passing to dark blue			
Rhodium	10·65	White	B	...	...	180+	Zinc?	.....	.....	.....		
Iridium	18·68	White	M	...	...	180+	Do.?	.....	.....	.....		
Uranium	9·0	Grey	B	...	...	170+	Ferrocyanate of potash	Brown-red	Chocolate	Brown-yellow		
Titanium	?	Yellow	B	...	...	170	Inf. of galls	Grass-green	Red-brown	Grass-green		
Cerium	?	White?	B	...	...	...	Oxal. of ammonia	Milk-white	Red-brown	White	Brown	
Potassium												
Sodium												
Lithium												
Calcium												
Barium												
Strontium												
Magnesium												
Yttrium												
Glucinum												
Aluminum												
Thorium												
Zirconium												
Silicium												

Reciprocal Combinative Potencies of the Metals.

The investigation of the conditions under which the metallic oxides reciprocally solicit each other is alike peculiarly interesting and important, inasmuch as it involves, directly or indirectly, the whole theory of enamel colours, coloured glazes, and coloured dry bodies. And, separate from this Art, it likewise regards that of metalline pigments, and numerous particulars in General Chemistry. The activity of philosophical inquirers has not yet succeeded in removing all the obscurities and developing all the peculiarities of the subject, and probably the very complex results cause the paucity of current information concerning them.

Essential conditions of the problem are, the reciprocal action, the momenta and consequent oxidation, also the different potency of each metallic oxide to solicit and neutralise the respective acids.

By clearly developing the succession in which metalline solutions precipitate oxides, there will be simplified one part of analysis, as well as the purification of the metallic salts. The illustrations annexed will probably remove much of the obscurity and complexity which have involved this subject to the present time. I cannot help thinking, that if from the whole of the facts detailed there can be discovered any necessary and direct connection between the results of the analysis and the practical fabrications—between the principles developed by the one, and the effects supplied by the other—most of the doubts would be removed, most of the difficulties overcome, the obscurities illustrated, and

theory conjoined with experience would lead to a complete solution of the problem.

Each metal, and even each different oxide of the same metal, to oxidise needs a certain and peculiar temperature. Lead at one temperature is minium, at another massicot. Oxidation ensues when the reaction of the potency of the metal and that of oxygen exceed those of concentrated oxygen present in the galvanic circuit; and only does it ensue from fusion when the potencies exceed those of atmospheric pressure which cause cohesion. It also ensues on disturbing the potencies of a compound of oxygen and some base. The degrees are constant and determinable specially by the properties of the salts formed, whose colours do not always indicate their metallic base, and which salts are usually neutral, neither aciduline nor alkaline. These degrees are designated by the colour name for common use, and by suitable prefixes for the scientific; thus we say either the black or red oxide of iron, the *prot*, *deut*, *trit* oxides of gold, the *per*-oxide of tin, for the first, second, third, greatest or maximum state of oxidation, and *hydrate* when water is present in even a minute proportion.

The presence of *dry* air, as well as of the atmosphere at usual temperature, will readily oxidise arsenic, manganese, and the metals developed by Davy, but only sluggishly and when previously moistened does the air oxidise copper and lead. At high temperatures, iron, zinc, copper, tin, silver, gold, etc. oxidise in distinctly coloured products.

Each metal in its pure metallic state is indifferent to the soliciting of any acid, and receptive

of the potencies of only the non-metallic elements, oxygen, chlorine, carbon, sulphur, phosphorus, hydrogen, iodine, and bromine, because of which they unite with compounds. The different proportions solicited by the same metal are few, definite, and ever analogous; the several results differ only in the multiple proportion present in the minimum to the maximum.

The acids have greatest potency, then the alkalies, and afterwards water, in soliciting metallic substances to combine with oxygen. When a metal is solicited, only can oxygen be supplied by the water present and in contact; in the alkaline liquid the hydrogen evolves, the oxygen solicits the metal, and the fresh oxide (like one exhibited) is solicited by the potency of the alkaline liquid. When exposure to the air supplies an additional dose of oxygen, the resulting oxide differs from the prior one, and is precipitated with a portion of the acid, precisely that quantity supplied, and therefore not decomposed. Iron and manganese supply instances.

The presence of water with manganese, iron, zinc, uranium, nickel, cobalt, etc., will supply oxygen for the oxide to have the maximum, like as would result from acids, or the minimum from the aciduline solution. Indeed only when water is added to concentrated sulphuric or muriatic acid, and after hydrogen gas has evolved with more or less effervescence, will iron or zinc oxidise and become soluble in the liquid. The strong combinative potencies reciprocally of the oxygen and sulphur prevent the result until additional oxygen is supplied by the water, and the equilibrium is disturbed. The

weaker these potencies are, the more will be obvious those of the oxygen in soliciting the metal. If we substitute for the metallic iron its peroxide, no gas will evolve during the solution; and because of the weakness of these potencies in nitric acid is its ready and energetic soliciting of iron and zinc.

In proportion to the doses of oxygen (or chlorine, etc.) present in the metallic salt, or of the acid in the neutral salt, does water solicit these products to combination, and least does it solicit those with the minimum; but its solicitings are always in definite proportions, multiplies of the minimum. When the result has a quantity of water equal to that of the basic salt, or oxide, the hydrate has more potency than when only in the quantity supplied by the acid. This is another proof of the use of dilute acids. The hydrate of each common metal precipitates when the oxide dissolved in sulphuric, nitric or muriatic acid is solicited by the proper alkali (potash, soda, or ammonia); to obtain this as an hydrate, not an oxide, filter out and dry at about 100° Fahrenheit. Ignition dissipates the water of the earthy hydrates; but those of potash, soda, lithia, barytes, strontia and lime require it to be intense, or else to be accompanied by some potencies with momenta greater than their's towards the water. On water soliciting a metallic chloride, as the chlorine combines with the hydrogen, muriatic acid results, saturated with the oxide formed by the oxygen liberated from the decomposed water.

The paucity of positive information on these subjects caused the opinion that, by instituting a

series of experiments, I should attempt a task of some utility, and which would contribute to augment and improve our knowledge. The philosophic inquirer never feels humbled at correcting or extending his stores; nor will he wholly disbelieve a fact, because not in unison with his received opinions, or one to which he cannot adduce some parallel instance. Else he would insurmountably oppose the progress of science, by substituting his own feelings in place of Nature, and by attempting to measure what is immeasurable by the limited scale of human comprehension.

Mix a little of a solution of red sulphate of iron with much of one of green sulphate; add test 1, equivalent to the red; agitate well; the first supply of the test causes a precipitate of peroxide entirely free from protoxide, but the additional supplies precipitate both oxides together. These precipitates filter out; and the filtered liquid shows the entire absence of oxide of iron, by being limpid, and not rendered blue by test 9, nor black by tincture of galls. By reversing the process, adding little of the green to much of the red, and adding test 1, all the peroxide precipitated first, and afterwards the protoxide. Therefore, as the protoxide of iron precipitates the red, we easily can prepare green solutions without any peroxide.

Consistent with the principles of mechanics, as action and quiescence are always equal and opposed in compound engines, only when the elements combine properly in definite proportions has the compound efficient combinative potency. When any precipitant solicits to combination the oxygen

of the metal precipitated, the reciprocal momenta of the two metallic oxides towards the acid promote combination in a degree inferior to the potency of the oxygen. Hence the precipitate usually is spiced with the precipitant. Caustic alkali added to a metallic solution usually spices the oxide precipitated, and occasionally dissolves it. Carbonated alkali thus employed precipitates the oxide as a metallic carbonate.

The sulphate of zinc of commerce frequently has iron present (the true cause of difference in the tint of *mat blue*). To a solution of sulphate of zinc add test 1, agitate well, and heat to 180° Fahrenheit, which will cause to precipitate oxide of zinc and a little peroxide of iron. Test 9 will by a blue tint show the presence of protoxide of iron. The liquid divide into two portions, and acidulate one with nitric acid, and boil 15 minutes, and the other with muriatic acid; to each add test 1; the iron precipitates, leaving a solution of pure sulphate of zinc, with a spice of sulphate of potash. Oxide of zinc precipitates peroxide of iron, and is precipitated by the protoxide. The combinative potency of nitric acid with zinc leaves free much of the peroxide of iron, which precipitates, and what remains has excess of acid, and is separated by exhibiting more zinc. But when the solution has been slowly made, much of the iron is strongly retained, because protoxide.

Frequently is a metal oxidised by the exhibition of its oxide, and likewise by that of an aciduline solution of the oxide, because of the acid's varied combinative potency with different oxides,

even though much exceeded by that of oxygen. The peroxide of a metal being more potent, and requiring acid equivalent for each salt with the oxygen of the oxides. In the neutral salts the distinctive potency of the components is scarcely recognised. But when to one portion of such salt another portion of one component is exhibited, a compound results whose potencies are completely different. The tartrate and bi-tartrate of potash are good instances. In all these and similar experiments, according to the alkali exhibited, the one or two oxides will precipitate, but to render the phenomena more obvious, carefully drop in the test, to precipitate one oxide, and pour it in to obtain both.

By almost similar processes I noticed that the peroxide of iron is precipitated by deutoxide of copper, yet this is precipitated by the protoxide. Hereby we can readily separate all the iron from a solution of copper, and all the copper from a solution of sulphate of iron. This will suggest a remedy for the altered tints of those colours prepared from sulphate of copper, and where iron has spiced the salt, and not been completely separated. When, to accomplish this separation, the peroxide of iron is formed by nitric or muriatic acid, add test 1, agitate, and at the temperature of 180° will precipitate all the sulphate of iron.

In the Arts also is often used green sulphate of iron, which should not be spiced with copper. Iron separates it only imperfectly, and after long repose. To the solution of green sulphate of iron add test 1; agitate the liquid; the protoxide rapidly precipitates

in company with the deutoxide of copper, leaving in solution whatever peroxide may be present. When the liquid is alkalinised with test 2, to precipitate the deutoxide of copper, rapidly is the protoxide of iron dissolved, though in like circumstances this test 2 does not dissolve the peroxide. Exposure to the air separates the solution, ammonia evolves, and a black pellicle on the surface soon precludes further atmospheric action. In analysis test 2 is useful to precipitate peroxide of iron when present with nickel. In an aciduline solution the perchloride of mercury quickly precipitates the peroxide of iron, and the oxides of zinc and copper. And in any aciduline liquid suspected to contain metalline particles, by a thread suspend a needle 24 hours, and around it will be precipitated whatever metal is present.

A nitric solution of silver frequently has a blue tint because of the presence of copper. Add test 1, and there is a flocculent precipitate, chiefly of oxide of silver, where the test passed, which gradually solicits deutoxide of copper. Agitate the liquid, the oxide of silver will quickly be re-dissolved, and for it will be substituted the precipitate of copper. Alkalinise the filtered liquid with test 1, an insoluble precipitate results of oxide of silver, which when filtered out leaves the liquid colourless, and entirely free from copper. To supersede this exhibition of potash, separately precipitate, filter out, and wash well a part of the impure nitrate of silver, which again exhibit to separate the remaining portion of copper. This suggests a remedy for some failures in preparing purple. The oxide of silver will separate the nitrate of zinc in the analysis of

mat blue, and the oxide of manganese will separate the muriate of copper present in the gold solution for purple.

The precipitates must not be supposed pure oxides; the copper is always bluish-green, varying with the other oxides, indicating the presence of some acid.

The instances adduced are not numerous, neither are they sufficient to explain all, yet their consideration will develop some of the conditions of the problem: 1. There is a nearer approximation to equilibrium in momentum to render inert the potency of the acids between the protoxide of iron and the peroxide of mercury, which precipitates the peroxide of iron, the oxide of zinc, and the deutoxide of copper, than there is between any of the latter mentioned. 2. Likewise, for the same purpose, between the oxides of zinc and manganese, which precipitate the deutoxide of copper, and between either and the copper. 3. For the like purpose there is greater potency in the oxide of silver than in that of zinc, or of copper, which by it are precipitated.

In numerous instances we find the components of a saturated compound possess weaker combinative potency reciprocally than when one is present in a different proportion. But in every instance the potencies of the earths and metals render ineffectual all attempts for their volatilisation. There usually is present with the natural oxides much earthy matter, which being vitrified by the heat exerts considerable potency to retain the oxide in the vitreous mass; and this more especially when the ores rapidly sustain a short contact with the motions of heat, in

which instances, instead of a *regulus* of the metal (or a button of the metal, to which the term was given by the alchemists, as supposing it to contain a spice of gold, the *king* of metals), there results a fine coloured glass or paste.

This combinative potency of oxygen with the metals causes the employment of substances capable of fixing the oxygen, and receiving any portion evolved, which otherwise would be ineffectual during the application of the motions of heat. When carbonaceous materials are employed, and the metallic oxide is free from the solicitings of other substances, the metallic particles leave the added substance, and because of its greater fusibility, they precipitate to the bottom of the crucible, free alike from the oxygen and any acid present, although in combination with the alkali and earth of the flux they form one agglutinated mass of metal.

Many of the metals can, with great care only, be by fusion combined into permanent compounds, or *alloys*, always in determined proportions, possessing peculiar qualities, and adapted for only certain uses; much altered in their fusibility and volatility; frequently more susceptible to the solicitings of oxygen; their hardness and colour different from those of either component alone, and the specific gravity rarely the mean of those of the components, but less usually, and in a few instances greater than the mean.

Each metal affected by chlorine gas (always in either 9 or 18 multiples of 4) during the subjection to the motions of heat has the oxygen present in the oxide, superseded, and chlorine occupies its place in

either one or two proportions in the fresh compound. Of the facts of this combination we have no doubt whatever, though we do not always know the precise proportion. We likewise know that the potencies of cyanogen for metals are very strong, but for oxides very weak; the water present supplies hydrogen to form hydrocyanic acid while the oxygen solicits the metal.

Several metallic oxides precipitate alumine in aciduline solutions, because of greater momenta to render inert the potency of the acids. Glucine separates the salts of alumine; and its solutions, though not completely neutral, are more so than those of alumine. Both these, however, and also most metallic oxides, magnesia precipitates in aciduline solutions, and completely renders inert the acids.

A principal cause of the separation of bases in solutions is not the metal's susceptibility to the solicitings of oxygen, but its state of oxidation causing difference of momentum of combinative potency with the several acids. Thus several metals precipitate the peroxide of iron, yet are by the protoxide precipitated. Also several oxides with less oxygen present than there is in the oxide of zinc precipitate it, and yet zinc precipitates others under like circumstances. The protoxide of iron more potently than the peroxide solicits to combination muriatic acid, which may be the real cause of the former oxide precipitating the latter.

On exhibiting an alkali the precipitate retains some of the acid which promotes its solubility; because of this an oxide with much acid present more readily dissolves than one with less. The iron

precipitated from the red retains less acid than that from the solution of green sulphate, and this precipitate sooner dissolves than the other.

The ready solubility assists, but does not determine the mutual precipitations of the metallic oxides. The aciduline oxide of copper is precipitated by the neutral oxide of silver on adding test 1 to a mixture of their nitric solutions. Whenever the addition of another substance changes the condition of the menstruum, or by combining with the metal present renders it too ponderous longer to remain suspended, these will of necessity be a partial or entire precipitation.

In addition to those which economy requires, there are to be determined and satisfied other conditions, indispensable to the complete success of the process, by which are much diminished the number of chemical agents. The minute investigation of any substance individually, to be properly understood in all its peculiarities, requires so much time and patience as seldom to be a sufficient inducement to such an operose undertaking, and only is it pursued because of its being some way connected with other useful collateral subjects. In proportion to the novelty and importance of these interesting results do they require to be confirmed by the experiments of others. And whenever among results there is a difference, new inquiries are indispensable to detect the sources of the difference, and correct or remove all remaining errors.

The momentum differs in nickel and cobalt; hence that which most solicits the same acid will precipitate the other, and remain alone in the

aciduline solution. Glucine more potently than the peroxide of iron solicits the acids; hence to separate the iron we need only to effect its condition; that is, precipitate, filter out, and wash well one portion, and employ it to precipitate the remaining iron. And all the conditions being similar, those substances with greater momenta may cause the precipitation of those with less, when soliciting the acids.

Although, therefore, we may not know all the conditions of this mutual precipitation, we are certain that one is the difference of momentum of combinative potency. Because of this we can free: 1. A solution of protoxide from any peroxide of iron. 2. A solution of sulphate of zinc or of copper from any oxide of iron. 3. A solution of green sulphate of iron from copper. 4. A solution of silver from copper; and indefinitely with the number of the substances employed.

. . . . . .

In this important Art of Life is employed a larger or smaller quantity of each of the metals—Antimony, Arsenic, Bismuth, Chromium, Cobalt, Copper, Gold, Iron, Manganese, Mercury, Lead, Nickel, Platinum, Silver, Tin, and Zinc.

ANTIMONY.

We have the authority of Pliny (lib. xxxiii., c. 6) for the opinion, that the ancients had some knowledge concerning the oxide of antimony found in the ore of silver, now particularly named from its presence; and there is some probability that they likewise knew of its existence as a bluish-grey mineral, with metallic lustre, which as a sulphuret occurs in nature, and also now from the eighth century called *antimony*. With this mineral the Asiatics and Grecians coloured their eyebrows black. When Basil Valentine had discovered and promulgated the process of extracting the metal from the ore, it was named, for reasons already mentioned, *regulus of antimony*.*

The ore of antimony is usually found in imperfect octahedral crystals, and thereby is readily distinguished from all other minerals with which it might be confounded because of colour, fracture, hardness,

* This Basil Valentine was a monk of Erfurth, in Germany, and was a noted alchemist. Tradition states that having cast away some refuse of the mineral, some hogs took portions of it accidentally; it purged them violently, but afterwards they rapidly became very fat. His brother monks, by mortification, fasting, and long prayers, being extremely thin, Basil supposed that a like effect to that produced on the hogs would result from a dose of the mineral; he was, however, much mistaken; instead of growing fat, soon they died; and the substance which was so useful in promoting the health of hogs was the contrary to monks, and because of killing them was called *anti moine*.

and weight. Subjected to the blow-pipe flame it readily fuses, and afterwards volatilises in the state of a grey inodourous vapour (unless when spiced with arsenic); and when the assay has slowly cooled, it is covered with white, brilliant, acicular crystals.

Antimony, in its metallic state, has a greyish-white colour, with some brilliance; the texture laminated, the laminæ crossing each other in every direction. Its lustre diminishes, but no other changes ensue from the presence of atmospheric air or immersion under water; yet a current of steam directed over the incandescent metal so powerfully affects it as to cause violent detonation. When raised to the temperature of 810° it melts; and by additional rise in an open vessel it gradually solicits the oxygen of the atmosphere, and in a white vapour sublimes, forming what are called the *argentine flowers of antimony*—the protoxide, and the same peroxide when raised to a white heat and suddenly agitated. It crystallises in oblong figures perpendicular to the interior surface of the containing vessel, causing its texture to be laminated. When rubbed on the finger there evolve a very peculiar odour and savour; and on charcoal, in the blow-pipe flame, there is great brilliance, accompanied with a dense yellow smoke of oxide. It has almost like hardness with gold; its specific gravity is 6·702; it is extremely brittle, pulverulent in a mortar, and has a tenacity that capacitates a rod one-tenth of an inch in diameter to support about 10 lbs. weight.

The protoxide, composed of two doses of base to one of oxygen (A 22 + O 4 = 26), is of a dirty

white colour, devoid of lustre. It can be obtained by this process: The metal treat with test 26 till it is completely separated, and to the liquid add pure water until all precipitation ceases. This precipitate is a submuriate of antimony; filter out, wash well, dry, and then boil in test 3; again filter out, wash well, and dry on the filter. When this precipitate is raised to incandescence it melts, and in a retort can be kept fused a long time, but exposed to the atmosphere it ignites, solicits oxygen, and is converted into the deutoxide (A 4 + O 3, or 44 + 12 = 56), or antimonious acid (*glass of antimony*).

The most plentiful supply is from the Huel Boys, Endellion, Cornwall, and Saltash, near Plymouth; and also from near Presburg and Puy de Dome.

ARSENIC.

ARSENIC (the white oxide of commerce, the arsenious acid of analytical chemists), is semi-transparent, brittle, faintly sweetish, without odour, volatilises at 380° Fahrenheit, and in a quick rise of temperature vitrifies. It is a violent poison in vapour, or applied to a wound, or taken into the stomach. It is sparingly soluble in water, and readily combines with the alkalies. It alloys cobalt, antimony, tin, copper, lead, and some other metals, rendering them brittle compared with their condition when arsenic is not present. The mineral kingdom plentifully supplies it in masses, black, ponderous, slightly brilliant; and also in two native sulphurets, distinguished by their colours, the yellow sulphuret, *orpiment*, lemon or greenish-yellow; and the red sulphuret, of a ruby red tint, *realgar*, more transparent than the former; and they are produced artificially by dissolving white arsenic in test 26 and precipitating by test 13, and by incandescing white arsenic with sulphur.

It is employed in some glazes to advantage; because while as a flux it promotes the fusibility of the components, its ready volatilisation capacitates it to dissipate and carry away any carbonaceous matter present in the alkali employed.

CHROMIUM.

During about thirty years, or from 1798, when the native mineral, *chromate of iron* (a compound of 1 atom of chromite of iron + 1 atom of chromite of alumine), was first introduced to the attention of chemists, concerning its nature there was great difference of opinion, up to 1820. The mineral having gained the attention of Vauquelin, and been found in serpentine rocks in different parts of the old and new continents, and some of the Shetland Isles, the researches of different analysts have been rewarded with the results of a peculiar acid combined with basic iron. This acid reduced with charcoal has supplied a metal, which, however, has not been employed as such in the Arts.

Chromium has a white colour, intermediate between those of tin and steel; its specific gravity 5·90, extremely brittle, receiving a fine polish; giving to the action of the magnet less recipience than iron, nickel, or cobalt; sustains scarcely any alteration because of being kept under water; does not solicit oxygen during exposure to the atmosphere; yet it does so, and gradually becomes oxidised, at a high temperature. It is sluggish to the solicitings of acids, even at a boiling temperature; and by nitro-muriatic acid is solicited, and forms muriate of chromium. It will sustain an extremely high temperature, not yet precisely determined, but above 170° of Wedgwood's pyrometer; and in that of the biscuit-oven for hard porcelain it is reduced

into small grains. Its combinations with oxygen form the green, brown and yellow oxides.

To obtain the chromium; *Process.*—The mineral chromate of iron in very fine powder, two parts, and one part of nitrate of potash well mixed, fuse together during two hours at a high temperature, in skittle-shaped crucibles for the large processes; otherwise, for experiment, in a silver crucible when convenient. When cold, break the crucibles, and the whole of the spongy mass with the shreds cover with ten times their weight of pure water; boil one hour; the liquid, when cool, decant off, and the residuum similarly treat, until no more colouring matter is supplied. The water then very slowly evaporates to one half; add test 25, filter out the silicate and the aluminate of potash; again add test 1 till the liquid is alkaline and has a yellowish tint. The evaporation is repeated slowly, cool, leave the liquid to repose that the nitrate of potash may crystallise, with scarcely any of the chromate of potash of the liquid. This evaporate to a pellicle, and abstract the beautiful crystals of bi-chromate of potash; which process repeat for a second supply; and the remaining supernatant liquid again evaporate to supply the neutral yellow sub-chromate of potash.

2. The calc pulverise, and in plenty of pure water digest 1 hour; after 24 hours' repose carefully decant the liquid by employing the siphon; to the precipitate add test 26, agitate, and after two minutes by the siphon abstract the aciduline liquid. To the residuum add, as before, one-fourth of nitrate of potash; again calcine for two hours, and repeat the treatment till all the mineral is suspended in the liquids. These last evaporate one half; slightly acidulate with test 25, and continue the evaporation till a pellicle forms on the surface, when place the liquid aside to crystallise, and separate from any impurity present. The salt thus obtained pulverise and mix with water, then again slightly acidulate with test 25; evaporate as before, and obtain all the crystals of nitre by a repetition of the process; the menstruum again evaporate, let it repose 14 days, remove the yellow crystals, dissolve in pure water, again evaporate, and crystallise for *chromate of potash* (P 1 + C 1 + O 2; or 10 + 7 + 8 = 25). Or, to the solution of the salts add test 20; the orange-red precipitate of *chromate of mercury* (M 1 + C 1 + O 2, or 25 + 7 + 8 = 40) filter out,

wash well, evaporate dry, and in a porcelain retort raise to incandescence, and there will remain the protoxide in a state of purity. Richter obtained the metal by mixing the protoxide with sugar, and exposing the mass to the temperature of a porcelain oven.

From chromium we obtain the protoxide brown, the deutoxide green and the acid, orange-yellow, whose components respectively are—C 1 + 1 ox., 7 + 4 = 11; C 4 + 3 ox., 28 + 12 = 40; C 2 + 3 ox., 14 + 12 = 26.

Processes.—1. *Green Oxide.* In muriatic acid digest the ore, and when the acid is fully saturated, or the mineral completely in suspension, evaporate dry, and by raised temperature dissipate excess of acid; mix well in pure water, add test 2, filter out, and wash well the precipitate; again evaporate the liquid, and add test 2; filter as before, and when evaporated dry incandesce the salt.

2, 3, 4. Ignite in a close vessel chromic acid, oxygen will evolve, and leave the green oxide. Or, ignite together chromate of potash, carbonate of potash, and sal-ammoniac; or, chromate of lead and some oil or charcoal; the *green* oxide results.

5. In water dissolve chromate of potash, then add tests 32 and 21 or 26, and boil well; allow 24 hours' repose, and filter out the greenish-blue hydrate, soluble in most acids, until it has been incandesced, when it becomes insoluble.

6. In tests 26 and 32, equal quantities, for 1 hour digest crystals of chromate of lead, and let it repose 24 hours; filter out, and wash well the muriate of lead with alcohol and with pure water; the liquid evaporate almost dry, and then incandesce in a platinum crucible. The oxide when precipitated from aciduline solutions is always of a deeper tint, readily soluble in acids, and has water present that is easily evaporated.

7. To the solution of chromate of potash add test 36 till precipitation ceases; filter out the chromate of barytes and wash well; add test 24, and digest 30 minutes, then filter out sulphate of barytes; with care evaporate, and allow to crystallise into ruby-red crystals, with some difficulty obtained, and with avidity soliciting moisture from the atmosphere; again mix in pure water,

and recrystallise twice for the *pure chromic acid*, which has a very sour and metallic savour, and deep red colour. The sulphate of barytes must also be examined, as with it may precipitate some oxide of chromium, and also oxide of iron or copper, if present. The acid has strong combinative potency with several of the bases, alkaline, earthy, and metallic, and with oxygen is separable only by very high temperature, yet readily by protoxide of iron, leaving protoxide of chromium. Sulphuretted hydrogen, sulphurous acid, and protoxides of iron, copper, and tin, convert the acid into the green oxide.

8. *Chromic Acid* from Chrome Ore.—Put equal weights of chrome ore and nitrate of potash into a crucible in an air furnace, and fuse at least 2 hours; when cold, wash all the calc out, filter, and the liquid will be a solution of *Chromate of Potash*. Acidulate with test 25, then add test 30, and when chromate of barytes ceases to precipitate filter it out, and in a capsule immediately add test 25 to dissolve it; then add test 24 very dilute, till the precipitate ceases, filter it out, and the liquid will be water, nitric and chromic acids; evaporate this dry, and by raised temperature dissipate the nitric acid, and the red chromic acid secure in well-stoppered phials. The solution is yellow, and with a concentrated acid forms the chromic oxide, whose solution is green.

9. In nitric acid dissolve the green oxide, evaporate dry, and then by raised temperature dissipate all nitrous vapours; filter out the brilliant *brown* powder, insoluble in acids, and only sluggishly soluble in alkalies. When test 26 is added, and the temperature raised, chlorine gas evolves, and the protoxide is formed, proving that previously more oxygen was present than now is in the protoxide.

The green oxide, at a temperature just below incandescence, is extremely combustible, and although sluggish to nitro-muriatic acid, is readily oxidated in a furnace, by fixation of oxygen, especially in presence of an alkali. When it becomes ignited the bulk diminishes by loss of its water, and the colour becomes a very deep green, almost black; at a yet higher temperature it inflames, and blazes

intensely 1 or 2 minutes, without either gaining or losing any portion of its weight; next it acquires the precise temperature of the combustibles around, and then its colour is a beautiful and fine light green with ·5 of water. Before incandescence the salt was readily soluble in acids, which is neutralised, but after this it becomes altogether insoluble, indifferent to the solicitings of acids, or alkaline leys, indicating that the reaction has caused a more intimate combination between oxygen and chromium, or at least, an increased aggregation in the particles of the oxide. Berzelius regards this phenomenon as very peculiar, because it occurs when a portion of the oxygen is disengaged, and the mass is reduced to a sub-oxide.

The chromic acid contains twice as much oxygen as the green oxide, and *one and a half* times as much as the base by which it is neutralised. Had twice as much oxygen been present in the green oxide as is requisite to form the acid, this dose of oxygen could not be a multiple by a whole number of that in the neutralising base, and if the green oxide contained thrice the oxygen necessary to convert it into acid, the quantity of oxygen in that oxide would seem incredible. Then the green oxide can contain of oxygen only half the quantity needful to form the acid.

COBALT.

This mineral has a grey tint, with rather a shade of red, and dull metallic lustre, the specific gravity 8·7. It is not hard, has very little tenacity, is rather brittle, and readily pulverised, malleable when incandescent, and its texture varies according to the degree of heat employed for its fusion ; it melts at 130° of Wedgwood's pyrometer, but by no heat is it completely volatilised. When incandescent it does not decompose water, neither does it, when cold, oxidise in air or water.

During several centuries has this mineral been employed to supply a blue tint to glass, but only during one century has any investigation of its chemical properties been instituted. Brandt, in 1733, obtained from the mineral the metal which he named Cobalt. In the edition of 1820, vol. I., p. 410, Dr. Thomson says : "Considerable attention has lately been paid to the purification of this metal, but, hitherto, no one seems fortunate enough to hit upon a method altogether free from objections." In Gehlen's *Journal*, vol. IV., p. 117, Tromsdorff publishes this :—

Process.—Mix intimately 8 oz. of pulverised zaffre, 1 oz. pulverised charcoal, and 2 oz. dry nitrate of potash, and into a crucible, in a state of incandescence, of this mixture project very small quantities, and let the whole remain at the same heat one hour ; then allow to cool, pulverise the calc, add the like proportions of charcoal and nitrate of potash, and thrice repeat the process of projection. After the third fusion, cool and pulverise the

calc, and add black flux 10 per cent., and during one hour keep incandescent; when cool, separate the metallic cobalt, pulverise, blend with thrice its weight of nitrate of potash, and this mixture detonate as already directed. Whatever iron is present will be formed into a peroxide, and the arsenic acid will combine with the potash, and may be separated by copiously working the pulverised mass in boiling distilled water; then filter, and well wash whatever remains on the filter. Having by this process separated the arseniate of potash, the contents of the filter digest in nitric acid, test 25, which will now dissolve the cobalt, and not solicit the peroxide of iron. Again filter, wash, evaporate dry, re-dissolve in test 25 to obtain any spice of iron which possibly may remain; filter this out, and wash well, the liquid alkalinise with test 1; filter out the precipitate, wash well with warm water, and the contents of the filter reduce in a porcelain crucible.

Dr. Henry says: "The ore dissolve in nitro-muriatic acid; add test 3, filter out the iron and arsenic; add more of the test, and the greyish-red oxide of cobalt precipitates. Incandesce the filtered metals, and the latter will volatilise."

When the mineral in an incandescent state is exposed to the atmosphere, it solicits to combination, in two proportions, oxygen, and the metal gradually becomes an oxide in powder, with 27·3 per cent., to form the deutoxide, cobalt 2 × oxygen 3, of a tint so dark as to seem almost *black;* and at a higher temperature this peroxide loses 9·5 to 9·9 per cent. of oxygen, and forms the protoxide cobalt 3 × oxygen 1, with a blue tint of varied strength from adventitious conditions. When this protoxide is subjected to a very high temperature a red flame evolves; and as any alumine present receives from this a blue tint, I assume that the metal is partially volatilised. The oxide gives the most beautiful *blue* tint, first to silica, and next to alumine; which tint is

rendered greyish, proportionately to the magnesia, lime, chalk, or Paris white, present during the baking, and it is almost violet when iron is present.

In the several steps of the process it is observed that carbon covers the outer film, or surface, to saturation; the next interior film solicits and appropriates a considerable portion of this carbon, and after it is almost saturated again is the outer film saturated; the like result ensues with a third film, and in succession, until the most interior is fully saturated, and the others to the exterior. During the state of incandescence the surface of the metallic bath, saturated with carbon, has this solicited by the oxygen of the air, and burned as carbonic oxide. This is replaced by other carbon, which exudes from the interior, as does water from a porous body, and is similarly solicited by the oxygen, and burned, until no more carbon remains present. By this process the metal is properly oxidised, as well as by the mutual reaction of the metal and the oxygen, in the repeated fusions, adopted for that purpose more than to separate impurities from the metal. Metallic baths being, like the surfaces of metals, in varied degrees affected by the oxygen of the air, whenever of two or more metals in combination (as cobalt and nickel; cobalt, bismuth, nickel, iron and arsenic), one, because of greater momentum, solicits oxygen with greater combinative potency than the other; while they remain in contact it will appear more potent, though not in combination, than the latter, which while really passive or receptive solicits only its regular dose of oxygen.

The mineral, in acids, is soluble without

effervescence. When the menstruum is test 26 the solution is green, but by dilution becomes light-red, similar to the solutions with tests 24, 25. Add test 1, filter out the precipitate, wash well, and dry in air, for the peroxide; and then subject it, during one hour, to incandescence for the protoxide. The protoxide is soluble in test 2, even though nickel may be present; and these may be separated by carefully acidulating with test 24, and then crystallising the liquid.

On drawing from the muffle a crucible of fused cobalt, when the surface appears congealed, place it in an inclined position, and while cooling there will be formed irregular prismatic crystals. The metal is magnetic.

The mineral is solicited and the metal oxidised by tests 24, 25, and 26 hydrogen evolving when 24 or 26 is employed.

The sulphate of cobalt (whose elements are Cob. 1 + S. 1 + Ox. 2, or 7 + 4 + 8 = 19) can be crystallised by the usual process of evaporation till a pellicle forms on the surface, and then left to cool; and these crystals on being distilled lose 42 per cent. of water, become opaque and rosy, and thus, without being decomposed, can endure a red heat, except the portion immediately in contact with the retort. When the sulphate is separated in water, add test 3 till all precipitation ceases, which will be when about 40 per cent. of the sulphate is decomposed. This precipitate is soluble in excess of the test, and also in water at any heat. The retort completely fill, and gradually heat to dissipate the water and carbonic acid, when will remain 60 per cent. of greenish-grey

pure protoxide (without this care, a portion will be peroxide, as verified by oxygen evolving when test 26 is added). This grey oxide is soluble in test 25, without evolving nitrous gas ; and by heat in open air is rendered black, a mixture of prot-and per-oxide, the former soluble in acetic or other weak acid, and in test 2.

With test 1 alkalinise boiling water, and add test 33 till the blue precipitate ceases ; continue the ebullition till the precipitate forms a rosy hydrate. When cold water is employed, instead of a hydrate resulting the blue precipitate becomes green, changeless by contact of air, or drying evaporation. And when recently prepared, boiling in test 1 renders this latter a reddish-grey—a mixture of hydrate and black oxide. The first of these three precipitates dissolves in weak acids, which separate the black oxide from the other two ; and oxygen does not evolve on adding test 26 to the blue oxides, as when added to the green. This most pertinently illustrates the reciprocal combinative potencies of oxides of the same metals.

The blue oxide results from the metal being solicited by oxygen from the air present in cold liquids—but whence results the green ? This beautiful characteristic grass-green oxide cannot result from a mere mixture of the blue and black oxides. Only chemical combination forms a tint different from that of the mixture of its components ; and it only can prevent atmospheric action converting into peroxide the portion of blue oxide present in the green precipitate, which latter only by evaporation and drying is completely oxidised. Only is the

blue protoxide soluble in acids. The green oxide is never supplied by any solution, nor is it the base of any salt.

The grey oxide put into a phial of test 2, stopped close instantly afterwards, imparts a rosy changeless tint, showing the slow momentum of the alkali to combine with the metal. But carbonic acid, on admission of air, or the presence of a carbonate, readily excites the momentum, and the colour quickly results. When the test is merely saturated with carbonic acid the liquid is a compound solution of oxide of cobalt in carbonate of ammonia; but a continued supply of carbonic acid makes the solution of carbonate of cobalt in carbonate of ammonia, which in a full and closed phial deposits crystals of metallic carbonate (also, on adding water, a portion precipitates) resoluble in excess of test 2. Carbonate of cobalt and carbonate of soda readily form this solution.

On adding test 2 to super-carbonate of cobalt it solicits the acid of one portion, which latter as a hydrate precipitates, while the other dissolves in the solution of carbonate of ammonia. Also, well-washed and dry hydrate, or blue oxide, in a full phial of test 2, instantly stopped, after 24 hours tinges the liquid red, like the preceding. But there is a great difference; the precipitate, on pouring this very slowly into boiling water, is the blue oxide; into cold water, is the green. The extreme comminution of the recent hydrate and blue oxide renders them more soluble than the grey in test 2.

Hydrate of Cobalt.—Crystals of sulphate or nitrate of cobalt add to a phial filled with test 1, and

instantly stop close. The salt precipitates blue, then assumes a violet tint, and lastly forms a rosy hydrate; which, filtered out, washed, and boiled in test 1, supplies some oxide, and becomes a most beautiful blue colour. Adding water separates the solution, and admitting the air precipitates the black oxide. The recent rosy hydrate is soluble, and tinges test 1 red; the oxide is insoluble. Also the hydrate is soluble without effervescence in heated acids, but not by boiling in either pure water or alkaline ley. Heat evaporates 20 per cent. of water, and leaves a grey oxide pure, changeable under water, and rendered black by the atmosphere. Dry hydrate keeps better, yet it solicits carbonic acid from the air. But substituting test 2 for 1, the blue precipitate is changeless, and never becomes rosy. The hydrate formed, instantly solicited by the alkali, tinges the solution.

The peroxide is insoluble in tests 1 and 2, and soluble in 24 and 25 only after being converted into a protoxide. With test 26 oxygen evolves. With sulphurous and nitrous acids it forms a protosulphate and protonitrate. Distillation forty minutes in a retort dissipates the oxygen, and leaves the grey oxide; applicable to tinge vitreous bodies.

The grey oxide in test 26, heated, forms a deep blue muriate, easily supplying crystals of blue chloride, which atmospheric moisture renders red. The solution of black oxide is green until the oxygen ceases to evolve, when it becomes blue; which traced and dried on paper exhibits an hydrous chloride—unless a spice of nickel supply a yellow tint, and so is formed a green. A chloride results from incandescence in a luted retort; the portion of salt in

contact with this decompose, and tinge it blue; the other portion sublimes of a gridelin tint; so condensed that the solvency of water often is sluggish more than twelve hours in commencing the formation of the muriate.

Arsenite of Cobalt.—Into a solution of arsenite of potash pour a dilute solution of cobalt salt; filter out and dry the rosy precipitate; then decompose it in a closed tube; the arseniac acid sublimes, and the glass is tinged blue. The resulting salt is soluble in test 25, and nitrous gas evolves. Adding test 15 to its muriatic solution it precipitates orpiment, but test 1, warmed, precipitates the blue oxide. The *arseniate of cobalt* results when the arseniate of potash is substituted for the arsenite. The precipitate also is rosy, and soluble in test 25, but in the tube it becomes violet, without tinging the glass. And adding 15 to the muriatic solution only produces a result after many hours' repose. Test 1 acts as by the other, and solicits the acid.

Humid Separation of Nickel from Cobalt.

The celebrated Hermstadt having directed to "dissolve the spiced salt in ammonia, and evaporate the solution," Bucholz (in 1803) tried these processes:—

(1.) In nitric acid, at 1·220 heated, with equal volume of water, dissolved 1 oz. of cobalt ore (*speiss*); three drams of crystallised arsenious acid precipitated, and was filtered out. On adding to the liquid half a volume of water, it assumed a dull-green tint; being again filtered, and treated with six volumes more of pure water, precipitated a spice of oxide of bismuth, which was re-dissolved by adding test 2. The next filtration supplied a mixture of arseniate of cobalt, and oxides of bismuth and iron. The filtered

liquid had a beautiful blue tint, and by gentle evaporation supplied about two drams of a bright green residuum of oxides of nickel and cobalt; and rapid evaporation supplied a like result. The deep green saline result of ammoniacal nitrate of nickel thus supplied, was re-dissolved in water, filtered, and boiled in test 1 till all the ammonia was dissipated, when 1½ drams of oxide of nickel was obtained, apparently free from oxide of cobalt.

(2.) The preceding process being operose and indefinite, he tried sulphuric acid. To the like weight of cobalt ore the same quantity of water was supplied, the temperature raised, and sulphuric acid added till all was dissolved, chlorine gas evolving (to his great surprise). The resulting precipitate was dissolved by test 2, except a residuum, much like verdigris, mostly oxide of cobalt, slightly spiced with oxide of nickel. The liquid being condensed by evaporation, and filtered, supplied more cobalt similarly spiced. It was next rapidly evaporated properly for crystallisation, and left to repose forty-eight hours, when were formed groups of green prisms, and masses of blue-edged crusts, both having almost equal proportions of cobalt present; as verified by the assay of the oxides procured by potash from the solution of the crystals, and from the menstruum.

(3.) On subjecting 8 oz. of cobalt ore to the process already mentioned, the first, bluish-green crystals, about 5 oz. were dissolved in 3½ oz. of boiling water, then properly evaporated, filtered, and left nigh a stove to cool slowly and crystallise. After forty-eight hours were formed beautiful yellow-green short rhomboidal pyramids, whose faces and angles proved cooling preferable to slow evaporation for forming regular crystals. All were carefully collected, well washed with pure water, then re-dissolved, and boiled with test 1 till all the ammonia evolved, and all the nickel was separated.

(4. *Most efficient.*) Equally to dissipate the carbonic acid, and to determine the absence of cobalt, this oxide was dissolved in test 25, and the solution alkalinised with test 2. The fine blue liquid by filtration supplied 5 grains of what seemed oxide of cobalt. The whole was evaporated dry; the residuum was re-dissolved in test 25, and on adding test 2, four drams precipitated of a beautiful bright green oxide. The filtered liquid, treated with test 1 at 212° Fahrenheit, supplied 170 grs. of pale-green oxide of nickel with carbonic acid. Some of this dissolved in test 26, and

applied to paper, by heat assumed a slightly greenish-yellow tint; but the oxide of nickel spontaneously separated during evaporation, being similarly treated, much chlorine gas evolved; and applied to paper, by heat assumed the tint of highly-saturated sympathetic ink of cobalt, proving more cobalt present in the solution than in that of the precipitate. The two oxides thus supplied, incandescence rendered dark grey; and in nitric and sulphuric acids, nitrous gas evolved from the evaporated residuum, and also the alkaline ley; and ammonia caused like results to those previously mentioned.

Therefore, the sulphates and nitrates of ammoniacal nickel separated from cobalt ore retain some cobalt, not separable by Hermstadt's process. And, partially decomposing, by evaporation, the ammoniacal nitrate of cobalt supplies an oxide of nickel, very rich in cobalt, but with nitric acid present; and the undecomposed oxide of nickel has very little cobalt present.

(5. *Laguier's.*) By well roasting the ore dissipate the arsenious acid; dissolve in test 25, filter, wash, and dry oxide of arsenic. Pass test 14 through the liquid, filter out, and wash the copper; boil to dissipate test 14; add carbonate of soda; filter out the precipitate, and digest in test 7 for the iron; add test 2, filter out the precipitate, and expose the liquid to the air; the tint, from a violet blue, becomes red; acidulate with test 7, filter out the deep green oxalate of nickel, wash well in boiling pure water; the red ammoniacal liquid evaporate dry for the pure cobalt.

COPPER.

This well-known metal, common in veins and beds in the mines of Cornwall, Anglesea, Spain, Germany, Norway, Siberia and America, is hard, sonorous, malleable, ductile, with considerable tenacity, and a peculiar reddish-brown colour, liable to tarnish and oxidise from exposure to the atmosphere. Its name originated from that of the isle of Cyprus, where it was first obtained and worked by the Greek, although long previously it had been known, probably as early as silver and gold; and before iron was so employed it was formed into vessels and weapons. It is harder than silver; its specific gravity is 8·830, or 8·895; its malleability admits of being hammered out into leaves so thin as to be blown about by the slightest breeze; it has considerable ductility; and its tenacity is sufficient for a wire 0·078 of an inch diameter to support 302·26 lbs. without breaking. Two bars of copper, one cast, the other hammered, a quarter of an inch in diameter, respectively supported, before they were broken, 1192 and 2112, almost double for the latter; and much greater is the difference in two wires of one-tenth of an inch diameter; the cast supports only 190·7, and the wrought 337·9 lbs. avoirdupois.

Pure water does not oxidise copper, but by it in a state of incandescence is decomposed, while its surface is oxidated; and the line of contact of water in a copper vessel is distinguished by a green acetate, or verdigris. At the common temperature of

the atmosphere, 60° Fahrenheit, in air the surface of a plate of polished copper forms very sluggishly and gradually a brown and a dark greenish-brown very thin crust of oxide, with carbonic acid gas; yet thin as is this covering, it preserves from further corrosion the metal beneath.

While approaching, but at a temperature much below incandescence, the surface of a plate of polished copper irridesces, or gradually becomes covered with beautifully-variegated marblings of prismatic colours, the red of each series being nighest the extremity most heated; and the orange, yellow, and blue tints forming the elegant foils employed to ornament children's toys. That these are results of oxidation, I assume, because the stratum of coloured matter is always thickest where has been applied the highest temperature, and it gradually diminishes or grows thinner towards the coldest extremity.

At a higher temperature, or incandescence, a plate of polished copper oxidises rapidly, its surface in a few minutes being covered with a crust of oxide, forming thin powdery scales, which when the plate is cool spontaneously separate, or may readily be rubbed of, because the plate itself had its dimensions expanded during the incandescence, and was so expanded while soliciting the oxygen, and while the oxide was formed; but having contracted to its primary dimensions, the oxide separates in scaly fragments.

This suggests a ready mode of obtaining a supply of peroxide of copper for the common underglaze *Black*. Alternately incandesce the plate of copper, and immerse suddenly in cold water; the scales

separate and precipitate in the water to the bottom of the vessel. The small portion of metallic copper which remains on their under surface causes them to seem violet-red; but when incandesced in air, they become the black and pure *peroxide of copper.* This black powder is devoid of savour, or lustre, or effervescence while dissolving in acids, and the menstruum is blue, or green, as it is test 24 or 26. There are different tints of brown, green, or blue with the peroxide, whose components are C. 1 + Ox. 2, and the protoxide, C. 1 + Ox. 1; native has a red tint, and artificial a fine orange. The flame of the fuel, during the incandescence, assumes a beautiful bluish-green colour.

At the temperature of 1150° Fahrenheit, or 27° Wedgwood (below that needed for gold and silver), copper melts, and its surface exhibits a bluish-green flame, like that of melted gold; and after fusion, when allowed to cool very slowly, a mass of crystals, of quadrangular prisms, are formed. At 40° Wedgwood it volatilises in visible fumes, partially metallic. When subjected to the oxy-hydrogen blow-pipe flame, the metal burns with an intense lively green light, whose brilliance is very oppressive to the eye.

A polished iron plate, immersed 24 hours in a liquid, aciduline by test 25, or 26, will solicit whatever copper may be present, and retain it as a metallic coating.

The tests 24 and 26 less, and the test 25 most potently, solicit copper; the oxygen combining with the metal while nitrous gas evolves, and the surplus acid is appropriated by the oxides. The deutoxide may be formed by dissolving the metal in 24 or 25;

then add test 1, filter out, wash, and completely evaporate the precipitate. The perchloride may be formed by gently heating test 26 in which is copper chips; decant the green solution, add rolled copper, and closely stop the phial; the green colour soon is superseded by a dark brown, opaque; many dusky white crystals form, which may be abstracted and again dissolved in water; to this, or to the whole solution, add test 1; filter out, wash, and evaporate dry the precipitate. The protochloride has a yellow tint, and the deutochloride is a yellowish-brown powder; when formed by igniting copper filings in chlorine gas, the former remains fixed, the latter sublimes. The muriatic solution supplies soluble, deliquescent, prismatic crystals. The colour of the precipitate, as green or blue, results from the potash, or soda, being less or more; and this has much acid, while it spices the other.

GOLD.

Gold is devoid of perceptible savour or odour; its specific gravity 19·3; its lustre not affected by exposure to air or water; yet inferior to that of platinum, silver, mercury and polished steel; it is remarkably flexible, but in hardness superior to lead and tin, and inferior to iron, copper, platinum and silver; in ductility and malleability surpassing all other metals. A wire of 0·078 of an inch in diameter will, without breaking, support 150·07 lbs. avoirdupois; yet this tenacity is not equal to that of iron, copper, platinum, or silver; one grain of gold can be beaten out into leaves $\frac{1}{282{\cdot}000}$ of an inch in thickness; yet this is 12 times the thickness of the gold which covers the silver wire of gold lace, for 1 oz. of gold on silver wire can be extended by the drawing-mill above 2,288,000 yards, or 1300 miles. In the focus of a burning mirror, or the oxy-hydrogen blow-pipe flame it fuses and vapourises. At 32° Wedgwood it fuses, is of a bright blue-green colour, and expands much; but on resuming its solid state it contracts more than any other metal, and therefore is ill adapted for casting into moulds; slow cooling crystallises it into short quadrangular pyramids.

Gold is among the metals first known, and it is supposed by many to have been the *first* employed for any useful purpose; and because of its scarcity and remarkable properties, as with the early societies it was estimated as most valuable, the like preference

continues to the present day. Almost the whole supplied to the market is found in a metallic state. It is the only metal of a reddish-yellow (almost orange) colour found in nature in a metallic state, most commonly in the sands of some rivers in Africa, France, Hungary and Brazil, in Wicklow, Ireland, and at Leadhills, Scotland, in minute irregular grains (called *gold dust*), also in ramifications, leaves, or crystals, in a matrix of a silicate, quartz, sand-stone, silicious schist, etc. When found native in compact masses, it is ever alloyed with silver or copper, or even iron and tellurium. The largest known specimen, scarcely alloyed, about 22 oz., hitherto discovered in Europe, and many smaller pieces, 1 oz. and upwards, were found beneath a stratum of turf on sand, near a small rivulet in the County of Wicklow, Ireland. It has been obtained by some of the French chemists from the ashes of vegetables. Hungary supplies *gelf*, argentiferous pyrites, with the gold ore either massive, or rhomboidal crystals, or irregular quadrangular or polygonal masses. The sulphuretted ores of Nagaya, in Transylvania, likewise supply gold.

A very high temperature is needed to oxidate gold in common air, because without this it will sustain incandescence an almost indefinite period. It can be brought into a state of purple oxide by the discharge of the electrical battery, or in the formation of the galvanic circuit, the focus of the large lens, and gas blow-pipe. The chlorides of gold and silver differ completely; the latter is extremely alkaline, partially soluble in water, and solicits all

acids presented; the former has none of these properties, yet at very high temperatures it is decomposable; while the latter, free from the contact of water and hydrogen, remains unchangeable by the highest temperature.

The only solvent of gold (also of platinum) is the liquid named *aqua-regia* (the *king's water*), but respecting the proportions of the component acids analytical chemists entertain different opinions. Proust directs, muriatic acid at 12° Beaumé, 800 parts, and colourless nitric acid at 40°, 200 parts, and a raised temperature (the latter to oxidate the former) to dissolve 187 grains of gold. Ure directs the proportions to be 33 and 67, and Davy 66 and 34, stating that there ensues reciprocal separation and combination, preparing the metal for combination with chlorine as long as it is evolved, but ceasing therewith. On the mixture of the two acids effervescence occurs, because the nitric acid solicits some of the muriatic acid, whose hydrogen appropriates sufficient oxygen from the other to compose water; and the nitrous gas is liberated while the chlorine remains to solicit the metal exhibited in small supplies till all is dissolved. The nitro-muriatic acid is usually orange-coloured, which changes to a deep yellow when saturated. When this is exposed to the solar rays the metal forms a hydrate, or an hydrous chloride, with just the equivalents of oxygen and hydrogen appropriable without excess to form water. And sulphuric acid exhibited will appropriate the muriate (or dissolve the chloride) and leave the nitric acid alone.

Processes—(1.) *To crystallise Gold.*—Add to the solvent excess of gold, next gradually add muriatic acid until its potency is inert, and consequently also that of the nitric acid; filter, and evaporate till a pellicle commences, then let it repose, and there will form laminated orange-coloured crystals; to be viewed only in the evaporator, because they are very deliquescent, and also separable by a moderate rise of temperature which dissipates the chlorine, and the metal is left with much water of crystallisation. When the solution is concentrated, the mass coagulates and the crystallisation is proportionately affected. I do not meet with any instance in which the employment of phosphorus has been tried in purposes of the manufacture. When the nitro-muriatic solution of gold is carefully treated with phosphoric acid, all the colour will disappear; pellicles of metallic gold will swim on the surface, and every atom of metallic gold will be precipitated.

(2.) *To purify Gold by Antimony.*—Take a good crucible that will contain at least four times the quantity put into it; bring the metal into fusion, and add twice the weight of sulphuret of antimony; cover up very close, and keep the fusion until the surface sparkles; then pour the fused mass into a strong iron cone hot and well greased; when cold there will be two compounds; the lower, gold and antimony, in the proportions of the metals sulphuretted; the upper, sulphurets of antimony and other metals which had been in the alloy. Repeat the process with the antimony, till only this and the gold remain. In a large crucible sublime the antimony, and with the bellows blow on the surface, and add a little nitrate of potash to complete the separation. Afterwards fuse the gold with this last, and borax, to get its ductile property restored.

Gold forms two salifiable oxides, the protoxide and peroxide; also a deutoxide not salifiable, but present in the purple of Cassius (which article see, Part II., Chapter 4). The peroxide is best known, because most readily obtained. The solution is slowly evaporated dry, and the residuum is dissolved in pure water; alkalinise with test 1, raise the temperature to 150° Fahrenheit, filter out, wash, carefully

evaporate, and dry the red-brown peroxide, G 1 + 3 Ox. ; a powder, with a styptic and metallic savour causing a flow of saliva, soluble partially in water or nitric acid, and readily in muriatic acid ; its oxygen dissipated by a moderate heat, and reduced metal remaining. When all the chlorine of the permuriate is dissipated, add test 1, and immediately filter out the green protoxide, because delay will present opportunity for one-third of the precipitate to appropriate the oxygen of the other two-thirds, by this reduced to the metallic state, while it forms the peroxide.

When test 2 is employed the precipitate is alarmingly and dangerously fulminative. On its early discovery, the alchemist Raymond Lully was very nigh falling a victim to its activity ;* and the greatest attention to washing the precipitate is needful, and to dry it on the filter laid on blotting paper. This fulminating potency is neutralised when the salt is immersed in concentrated sulphuric acid, this promoting the combination of the oxygen and hydrogen present into water which is by it appropriated. That the *ammoniuret of gold* is potent, more because of capacity than momentum, may be concluded from these facts : the oxide is solicited from the menstruum by the carbon organised and hydrogenated in the oils with ether

* Orschal, in recent times, experienced like danger. He was rubbing in an agate mortar this dangerous salt, when the explosion shattered the stone beneath his hand ; the sensation resembled the discharge of a musket load of sand full in his face, but did not cause a wound, or any other ill effect.

and alcohol, and nitrogen hydrogenated in ammonia; and the oils may appropriate the oxide, and also the ammonia, separate and distinct from each other. Ammonia is too indifferent to water for this to solicit it from gold, even aided by raised temperature, although this condition excites the potency of the compound, as, when washed with very hot water, the fixation of the oxygen separates the ammonia from the oxide, the hydrogen from the nitrogen, and the gold is left alone, while water results from combination of the elements evolved. The total impossibility of the salt being decomposed by acids will be clear from considering that they either must separate the ammonia, or at once dissolve both components: the former could be only by insulating, at a low temperature, the metal from its oxygen; the latter, only by the acids soliciting such oxide to combination; which, if possible, would increase, *ad infinitum*, substances with oxygen present.

When test 17 is used a beautiful purple precipitate results, which, applied to porcelain, is very deep, but only from one point of view. This precipitate partially dissolves by boiling in muriatic acid at 12°; and the potency of this acid on gold, as on other metals, is proved by test 18 supplying the purple precipitate of Cassius.

IRON.

Iron is distributed through the mineral, vegetable, and animal kingdoms in greater quantity than any other metal, combined with oxygen, sulphur, carbon, arsenic, and other mineralisers; and in almost a pure state large masses have been discovered, as in Paraguay, one of 300 lbs., and one of 1600 lbs. by Pallas, on the Denisei, in Siberia. Iron, when almost pure, has a slightly vivid whitish-grey or bluish tint, and considerable brilliance when polished. It is peculiar in giving sparks by collision with flint, and in being affected by magnetic potency, appropriating sufficient, under certain conditions, to affect other iron. The specific gravity is 7·6, the texture fibrous, granular, and laminated; the hardness, tenacity, ductility, and elasticity superior to all other metals; it can be drawn into wire finer than a human hair, and readily flattened by pressure; protected from contact with the fuel, it is refractory in the furnace; yet, preserving its ductility, it softens, dilates, and in this state possesses the important and valuable property of *welding*. At high temperatures it solicits oxygen from the air, and when intense, it scintillates, and forms a black oxide, I. 3 + 2 O. It likewise appropriates oxygen, from water, with rapidity proportionate to the temperature of the metal when exhibited; from the metallic oxides, from nitric, and diluted sulphuric acids; and is affected by alkaline compounds. Recently has been ascertained

a remarkable property of iron, never suspected till demonstrated by bringing to the shore the stores of the *Royal George*, which foundered in 1782: the guns formed of hard metal were unaffected, and those of iron are *softened by immersion in water*, so that a knife cuts them like pencil lead or plumbago. This will account for the frequent failures of the pump-trees in deep mines.

As only the oxides are employed in this manufacture, I shall state the readiest method to obtain them.

Processes.—1. *Protoxide.*—In water for several hours digest excess of iron filings; filter, and the liquid evaporate dry, covered from the air.—2. To a solution of protosulphate of iron add test 2; filter out, and in like manner dry the precipitate. This hydrate will change from black to white when dissolved in pure water.

3. *Deutoxide.*—In a porcelain tube place a coil of fine iron wire, incandesce, and pass through it a current of steam till the supply of hydrogen fails. This will not solicit oxygen from water, and therefore may probably become very useful.

4. *Peroxide.*—In nitric acid digest, some hours, clean iron filings; add test 2; filter out, wash well, evaporate dry, and slightly incandesce—the brown-red oxide.—5. In an open crucible calcine for two hours clean protosulphate of iron (green copperas); wash well, and evaporate dry—the *Colcothar.*—6. In like manner treat clean iron filings, for the red powder, *saffron of Mars.* Common iron rust is this, only with plus of carbonic acid.—7. In a current of air similarly treat the protoxide for a *yellow.*—8. Dissolve clean iron filings in sulphuric acid, dilute much, and expose constantly to the air; whenever the menstruum is saturated, precipitate by test 2, filter out, and evaporate dry. When pure, this is a *beautiful, fine, almost crimson-red.* If any yellow or brown tint be present, some impurity has crept in unobserved, and the process should be repeated. The result is insoluble in water, and sluggishly soluble in acids, more so than the protoxide, the liquid being sweetish astringent, with a yellow or brown tint.

LEAD.

LEAD is among the metals known from the earliest days of civilised society. When newly melted the colour is bluish-white, with some brilliance, which soon tarnishes in the air; and by soliciting the oxygen of the atmosphere, slowly the surface becomes a dirty grey, almost white oxide, which retards further soliciting and oxidation. Lead solicits oxygen from water chiefly when most affected by atmospheric action; hence the formation of a line of oxide at the part of a water cistern where the water remains a few days at the same level, and also the line of highest level. Lead has very little savour, but friction causes a peculiar odour to evolve; it stains the fingers bluish, and taken internally is poison. It is a very soft metal; its specific gravity 11·352, increased by hammering in a mould, but decreased by drawing, as wire, and lamination. Its malleability admits of being hammered into very thin lamina; its ductility is small; its tenacity causing a wire $\frac{1}{120}$ inch diameter to support 184 lbs. without breaking. Lead fuses and renders refractory metals fusible at 612°, and after fusion, when slowly cooled, it crystallises in quadrangular pyramids, lying on one side, and each formed of three layers; and at a very high temperature boils, and partially vapourises; and this continued, it vitrifies alone, or with other metals.

Lead solicits oxygen to combination, and forms the protoxide yellow, the peroxide brown, and the

red oxide, the others mixed. All of these being very easily vitrified, and in high temperatures first oxidate and then combine with other metals, except gold, silver, platinum, and those from this last; lead is employed to separate from gold and silver any base metal present, by the process named *cupellation* (from cupel, the vessel or test used—a shallow cup-like vessel, formed by pressing within an iron ring a mixture of bone earth or ashes, and wood or fern ashes, and scooping out the surface). Into this cup the alloyed metal is put, and kept at a high temperature till all the others with the lead vitrify together, and sink into the cupel, leaving the gold or silver.

The *protoxide* yellow (L. 2 + 1 Ox.) has been known longer than the others. Lead dissolved in nitric acid, and its colourless solution alkalinised with test 3, supplies a precipitate, which dried, and heated almost red, becomes yellow, tasteless, insoluble in water, but soluble in potash and in acids, readily fusible into a semi-translucent, brittle, yellow, permanent glass; also partially vapourising in high temperatures, and thus exposed to the air some time, the surface is rendered brick-red.

This last process, at a temperature rather lower, caused a grey pellicle to form as frequently as a prior one is removed, till the lead is all exhausted. These again exposed while heated and agitated form a greenish-yellow powder (supposed a mixture of yellow oxide and metallic lead), which being longer thus treated, the metal solicits more oxygen, and the whole becomes yellow—the article of commerce named *massicot*.

Ceruse, White Lead, subcarbonate. Thin plates of cast lead are curled up, and in skittle-shaped pots are exposed to the vapour of warm vinegar in a vessel beneath; rows of many hundreds in tiers are gently heated by bark and flues to volatilise the acetic acid, which gradually corrodes the lead into a white heavy powder, a compound of the yellow oxide and carbonic acid, though formerly supposed a peculiar oxide, and when ground in mills much like those for flint, and then dried, is fit for use either as a component of earthenware glaze, or as a paint.

Nitric acid, at 40° Beaumé, poured on red lead dissolves 185 parts, and leaves 15 parts as a deep brown or black powder. This is the peroxide, L. 4 + 3 Ox., or Scheele's *Brown* oxide.

Process.—Put red oxide of lead into a vessel of water, supply chlorine gas till the oxide is dissolved; add test 1, and 68 per cent. of the oxide will precipitate as a fine, light, tasteless, flea-brown powder, indifferent to tests 24 and 25, but solicits hydrogen from test 26; and by heat half the oxygen evolves, and the yellow oxide again is formed (L. 2 + 1 Ox.).

Massicot, in a fine powder, constantly agitated while the flame of the furnace plays on its surface 48 hours, forms the very heavy, beautiful, often intense, red powder, named *minium*, or *red lead oxide* (L. 4 + 3 Ox.), with specific gravity 8·940, tasteless; and unaltered in weight by 400° Fahrenheit, but by incandescence loses 4 to 7 per cent. as oxygen evolves, and part of the oxide is reduced to metal, the remainder being gradually vitrified dark brown. Only after decomposition does red lead combine with other substances, and because in its

plus of oxygen it sluggishly combines with acids, which first form the yellow oxide.

Galena, *Sulphuret of Lead* (having only the minimum of sulphur present), is that very abundant ore which supplies most of the lead of commerce, scattered in almost every country on the globe's surface; usually in cubical crystals, of a brilliant, deep blue-grey colour, brittle, and more refractory than lead in the furnace. Of *native* lead, pure galena, the pieces found, seldom of the size of a walnut, are distinctly cleavable, and decomposition coats them with a white meally sulphate of lead.

In extracting lead from the ore, each fodder always supplies from a few grains to 20 oz. of silver, and when the quantity warrants the expense, it is separated by the refining process, or cupellation; the lead by the flame gradually vitrifies, and either sinks into the test or is blown off, leaving the silver unaltered. The lead is converted into Litharge (L. 3 + 2 Ox.), which at first coheres in masses, but on exposure to the atmosphere separates into fine scales, partly red and partly golden-yellow, consisting of yellow oxide or massicot, combined with about 4 per cent. of carbonic acid.

The reciprocal combinative potencies of metallic sulphurets and litharge need consideration. According to the nature of the sulphuret will be the quantity of litharge required, from 5 to 30 volumes, to cause sulphurous acid gas to evolve, and either solicit the metal left to combination, or it remains as an oxide with the undecomposed portion of litharge. When the litharge is minus, of course its potency effects

only a portion of the sulphuret, and becomes sulphuret of lead, a very fusible alloy remaining.

Until very recently chemists supposed that lead and cobalt would not combine by fusion, although the blue-printed ware with lead-glaze might have suggested the contrary. But a direct combination has been effected by Gmelin, by rolling cobalt-powder up in a sheet of lead in different proportions, from 1 cobalt and 1 lead, to 1 cobalt and 8 lead, then covering the compound with charcoal to exclude the air, and raising the temperature to fusion of all.

Observing a fragment of cream-coloured ware on which the lead-glaze had run into a yellowish-green glass, I broke it for examination, and found numerous globules of lead in a reduced state; a remarkable crazing of the upper surface was presented, yet not at all in the portion immediately in contact with the body. Must we suppose that the expansion of the glaze had been regulated by the expansion of the biscuit, and its contraction was in accordance on cooling?

When a high temperature is given to lead in a glass retort on the commencement of fusion, the fusing portion is a bright yellow, and the other a dirty pale brick-red powder, and in a platinum crucible the resulting colours are the reverse. When lead is thus fused in the air a powder, *Lead Ashes*, is formed—a mechanical mixture of metallic lead with the protoxide, or massicot, which vitrifies into a greenish glass, with globules of lead present. The fusion of red oxide needs care, to prevent there remaining globules of metallic lead,

or the frit having a dark-brown tint. With much momentum the oxides of lead fuse, vitrify, and lose weight; the surface of the crucible is glazed with a yellow glaze, like some coarse pottery; and unless precaution is employed, some of the oxide may be dissipated.

Vanadiate of lead with phosphate of soda forms a beautiful emerald-green assay, in excess with borax, deep blue; could not some modification of these supply additional colours to the palette? The native mineral is chlorine 2·3, lead 7, protoxide of lead 66·3, vanadic acid 23·5, peroxide of iron, and silica ·163 = 99·463.

MANGANESE.

THE grey, black, brown, or reddish-white ores and carbonate of this metallic substance seem more diffused over the crust of the globe than those of any other, iron excepted, and have been during a long period employed to correct the impurities of fusing glass. Boyle was the first discoverer of it in England, though since his time many others have done so. Its great momentum in soliciting oxygen prevents its occurrence in the metallic state except with arsenic and sulphur. The article supplied by commerce always occurs in nature as an oxide, with different proportions of the dose of oxygen, yet without acidifying those with the maximum. Accompanied by carbonate of barytes, sulphate, muriate, and carbonate of lime, oxides of copper, lead, and iron, as indicated by soliciting the magnetic potency, the mineral is ponderous, with an earthy texture, amorphous and crystallised in prisms, tetrahedral, rhomboidal, or striated. The manganese of commerce is often contaminated with carbonate of lime.

Process.—Wash well in water 15, test 25, two parts; filter out, wash well, and evaporate dry. To liquid add test 7, to show the amount of lime.

Analyses.—1. In dilute nitric acid separate the foreign ingredients usually present in the ore of manganese; decant the liquid, and on a filter dry the residuum; this digest one hour in concentrated muriatic acid (12° Beaumé), then add carbonate of soda until no more white precipitate appears; this incandesce and it will become black. Or 2. Muriatic acid with raised temperature saturate with ore of manganese, and spice with test 25; evaporate half

of the liquid, add pure water, and then test 1, while any precipitate appears; during twenty-four hours immerse test 41, to cause deposit of the copper; which filter out, and add test 1 till precipitation commences; by test 8 precipitate the iron; repose twenty-four hours; add sulphate of soda when lead is suspected to be present. By test 5 precipitate any copper remaining, and digest in test 2. When the iron is abstracted, add test 2, and the precipitate will be oxide of manganese. Or 3. To the muriatic solution add test 5, wash the precipitate in test 2, dissolve it in test 24; alkalinise by test 3, digest thirty-six hours, and filter; add test 16, filter out and wash well the precipitate. Or 4. Mix black oxide of manganese 2, and test 34; fuse one hour, cool, dissolve the calc in distilled water at 212°; filter, evaporate, crystallise, and in a covered crucible calcine the crystals. Or 5. In water triturate the residue of the retort after the oxygen has evolved, or oxalate of potash and black oxide of manganese; add plenty of pure water; and by test 2 precipitate, filter, dry and ignite.

The peculiar metallic nature of this mineral was more than the skill of Bergman could develop; neither were the efforts of Scheele successful; but in 1774 Gahn adopted a process by which he accomplished the object of his research :—

Process.—Line a crucible with charcoal powder moistened with water; place therein a ball of the pulverised mineral agglutinated with linseed-oil; surround and cover with charcoal powder; over this lute another crucible; raise the temperature extremely high, and continue it eighty minutes; leave to cool; and at the bottom will be a number of metallic globules, usually about one-third the weight of the quantity of mineral employed.

I think every intelligent person will remark here the true cause of reduction: in the charcoal the oxygen evolved from the oxide became fixed, and the reduced metal remained in the crucible. Dr. Turner first detailed the chemical peculiarities, and

it is now well understood, that when the temperature of the bin-oxide (the Black Wad of the Upton-Pyne mine) is raised, one-fourth of the oxygen present evolves; and from pure ore, this is to the amount of 9 per cent., or one-eleventh of the weight. The three oxides have these proportions of components :—

	Protoxide.	Binoxide.		Red oxide.
Manganese	86·940	97·835	99·242	98·098
Oxygen	9·851	—	—	0·215
Water	0·949	1·120	—	0·435
Barytes	2·260	0·532	Iron 0·130	0·111
Silica	truce	0·513	0·840	0·337
		100·000	100·212	99·196

Manganesium is without savour or odour; has a whitish-grey colour, like cast-iron; fine granulated irregular texture, uneven fracture; metallic brilliance, soon tarnishing by the action of the atmosphere; specific gravity 8·013, softer than cast-iron, and readily filed; so extremely brittle it cannot be extended by the hammer, nor drawn out into wire; its tenacity consequently is not known; it surpasses all other metals in combustibility; though less fusible than iron it is a very refractory metal, requiring a temperature equal to 160° Wedgwood for complete fusion; whenever iron is present, the magnet will indicate it; and hence this is the test of the purity of manganesium; it can be protected from oxidation by immersion in alcohol, or oil; but unless thus protected, such is the momentum of combinative potency with which it solicits oxygen, that its lustre readily

fails, the colour quickly becomes red, violet, brown, and black, and in a much shorter time when exposed to the atmosphere during the rise of temperature; and in this condition rapidly decomposes most metallic oxides; and, in its separating water into elements, the hydrogen is affected by the metal, and the noisome odour of assafœtida evolves; it also similarly separates sulphuric acid, but is separated by nitric acid. When present in an alloy of gold, silver, or copper, brittleness of the whole ensues. Its great combustibility, and combinative potency with iron, are most useful in the Manufacture of glass; as all impurities are appropriated by these, and during the raised temperature are brought to the surface, off which they are skimmed. It is fusible with the earths, and the degree of oxidation varies the tint of the calc, brown, violet or red.

The peroxide is found at Upton-Pyne mine, near Exeter, and also near Nuneaton, in Warwickshire, a few miles distant from Coventry. This mine produces two species of ore, not always kept separate, in the mean :—

Protoxide.....	81·12	2 atoms binoxide
Oxygen	13·48	2 ditto susquioxide
Water	5·40	1 ditto water;

their specific gravities, however, are—black 4·531, brown 4·336; the latter is more pulverulent than the former; and at the usual state of incandescence evolves 10·1 per cent. of water; the other 5·725 water, and 7·385 oxygen gas. When pure, it has a radiated texture, dark steel-grey colour, with a beautiful lustre; it is brittle, very soft, and soils the

fingers; specific gravity 4·7563. When kept in a state of incandescence, rather more than one-tenth of the weight evolves in oxygen gas, the residuum being a brown powdery calc, devoid of metallic lustre.

Hitherto there has not been suitable attention to these oxides. The readiness with which they combine with earths, and promote their fusibility in a state of high temperature, renders them very useful in the *Mocha and dipped ware.* The colorific property suffers during the evolution of carbonic acid gas from carbonaceous components, till all the gas is dissipated, and then it can be restored (or may be protected) by the presence of nitrate of potash, which supplies a suitable dose of oxygen.

Processes.—(1.) In distilled water wash well some manganese in powder; evaporate dry; add half the weight of muriate of ammonia, and during twenty minutes incandesce highly; during this raised temperature the chlorine will be solicited to combination with the metal only, and the compound may be dissolved in water by careful washing. Add test 4, filter out the precipitate, place this in a green glass tube, and pass through this a current of hydrogen gas; the result will be the *Protoxide*, of an olive-green colour, when subjected to the action of the atmosphere.

(2.) (*Forchhammer's* beautiful *light green.*) In an open porcelain tube incandesce some grey ore of manganese; pass a stream of hydrogen gas through the tube, and the oxide will appear primrose-yellow; quickly take out of the tube, and put into a phial, which stop close, and it will become a beautiful green, but the oxygen of the atmosphere would cause it to become brown. Dry sulphate thus treated will supply a permanent light green.

(3.) Incandesce deutoxide, or carbonate of manganese, half an hour or more; or the muriate evaporate dry, and in a closed vessel incandesce the like time for the *Red* oxide. This will combine with bases, as 6 M. + 1 base.

(4.) (*Turner's.*) The residuum of the retort, after obtaining oxygen, mix with a sixth part of its weight of powdered charcoal; incandesce highly during thirty-five minutes; dissolve in muriatic acid, evaporate dry, and raise the temperature to fusion, which keep up not less than two hours; dissolve in pure water, filter; add test 8, and filter out the lime; to the liquid add test 4, filter, and wash well; form a vacuum with sulphuric acid, and dry therein; then dissolve in sulphuric acid, and the solution will be colourless.

(5.) *To separate metallic oxides.*—Muriatic acid saturate with the ore, then add one-sixth of nitric acid, evaporate one-fourth, then add three volumes of pure water; alkalinise with test 1, and immerse test 38 twenty-four hours to separate the copper present; filter; add test 1 to the liquid till it appears turbid; alkalinise with test 8 till precipitation ceases; then let repose twenty-four hours; add test 28, filter out the lead; add test 5, filter out and wash well the copper with ammonia and water; the precipitate dissolve in test 24, add test 3, then digest one hour, filter and wash.

(6.) The ore dissolve (as in 5), filter, wash well with four volumes of cold pure water; alkalinise with test 2 (to *blue* the test-paper just *red* by acetic acid); filter out and wash well the iron, evaporate dry, wash well, again evaporate, and incandesce to dissipate test 26, and the calc is *pure manganese.* Or, 7. The cold acid solution alkalinise with test 2, filter quickly; let the brown turbid liquid repose twenty-four hours, decant; evaporate the precipitate; also all the liquid evaporate dry for the oxide. There is much care needful, and also three or four filters, to quickly pass the liquid, and prevent any portion of the manganese in solution being deposited on the filter with the iron and earths.

PLATINUM.

THE metal thus named by the Spaniards, because of its colour resembling that of silver, has been known to Europeans only since 1749. Like gold (to which, with all the advantages, it is equal in some, and superior in several other valuable properties, as for the fabrication of instruments, vessels, and utensils, even for domestic economy, as well as for researches in Natural Philosophy, Chemistry, and the Arts) it is supplied by Nature in only a metallic state, yet always accompanied by various other metals; chiefly from Choco and Santa Fé, in South America, in crude small flat grains, with a silvery lustre. The largest known specimen, found in the Ural Chain in 1827, near the Denu Doff mines, is the size of a pigeon's egg; its weight is rather more than 9½ lbs., and is preserved in the museum of the Royal Society at Bergara; prior to that time the largest known mass was 11,641 grs. at Madrid, from Condoto. It is found in South America, Brazil, St. Domingo, Siberia and the Ural Chain. The ore is exceedingly impure, owing to the presence of nine other metals, four of which, palladium, irridium, osmium, and rhodium, are *new*, the productions of the laboratory; and, in addition to iron and chrome, are three others—copper, antimony, and lead. In the autumn of 1806 Vauquelin discovered platinum ore to the amount of 10 per cent. in the silver ores of Guadalcanal, in Estremadura (much like the grey copper

ores, the *fahlerz* of the Germans), in a gangue of quartz, carbonate of lime, and sulphate of barytes; in the company of lead, copper, antimony, iron, silver, sulphur, and arsenic; always entirely free from the four metals present with the ore from South America, and constantly among the sulphur and silica of the gangue. It is proved to be an accidental, not an essential component of the ore, by its very irregular distribution, from less than one to more than ten per cent., and with the silver from two to twelve per cent.

Process.—In nitro-muriatic acid (see gold, p. 328), with as little rise of temperature as will answer, dissolve the metallic grains. A portion of black matter will remain indifferent to the potency of the acid; decant off this the liquid, and into it carefully drop test 34; the orange-yellow precipitate filter out, wash well, evaporate dry, and then raise till incandescence commences, to expel the acid and alkali, and reduce the metal in an agglutinated state. Repeat the process, and the metal will be obtained pure. The powder or grains are next wrapped up in strong platinum foil, then incandesced, and by great pressure, or cautious hammering, they are rendered compact, and formed into an ingot. Or, on a support of strong marle, by the oxy-hydrogen blow-pipe fuse a few grains, to which while in fusion keep regularly adding a few more, until about one ounce is fused, when more in quantity may be added, until any required size of a piece is obtained; cut off the small part next the support, because with it will be present a spice of silica, that might deteriorate foil, wire, etc.

Platinum thus obtained, pure or refined, is the heaviest substance known. Its specific gravity, from the ammonia, chloride reduced by heat, is 21·5, and is by hammering increased to 21·5313. It is without savour or odour, with hardness between copper

and iron, considerably greater than gold or silver; with a white colour, to the eye like that of silver, but deficient in brilliance, and on the touchstone the two are not distinguishable; it is very malleable and ductile; it can be hammered into foil of remarkably thin leaves, useful in analytic processes, and it can be drawn into wire not exceeding $\frac{1}{1940}$ of an inch in diameter. Dr. Wollaston inclosed a thin wire of platinum in a fine tube of pure silver, and after this had been drawn out in wire to an extremely fine state, he digested the wire in nitric acid, which dissolved the silver, and left platinum wire not thicker than $\frac{1}{3000}$ of an inch. Its tenacity is such that a wire 0·078 of an inch in diameter will support 274·31 lbs. avoirdupois. Alone it is indifferent to the potency of the most concentrated acids singly, however high may be the temperature—as it also is to fusion in usual temperatures—so that the above is the only method of obtaining it in quantity. Alloyed it is fusible at a moderate temperature. When at a bright incandescence, two plates or rods can have their particles so welded together, like iron, as not to present the least appearance of having ever been separate. It is indifferent likewise to the action of air and water. The highest temperature of the furnace fails to excite combination of oxygen and pure platinum into an oxide, although it is sufficient to partially oxidate the metal from South America, because of the presence of iron, etc. But a better acquaintance with the metal will suggest the proper heat for accomplishing the purpose.

Processes—(1.) *To obtain the Protoxide.*—With pure water boiling hot dilute the solution of muriate of platinum; add test 20, filter out, wash well the coloured precipitate of chloride of mercury and protoxide of platinum; volatilise the chloride; the black protoxide left incandesce, and from 100 grains will evolve 12½ cubic inches of oxygen, or with lamp black, 12½ cubic inches of carbonic acid gas, and the metal is reduced. On enamels this will not suffer under the highest temperature of the muffel.

(2.) *For the Peroxide.*—To the solution, as above, add excess of test 24, distil this excess over; alkalinise with test 1, and the reciprocal potencies of the two substances will be obvious as remarkably strong, in the brown bulky almost insoluble triple salt which precipitates; filter out, wash well, dry, and raise the temperature till it becomes a brown or black powder; or when very high, is reduced because of the oxygen evolving. It dissolves with the caustic or carbonated alkalies, 1 and 2, also it combines with the alkaline bases, 5, 6, 7.

SILVER.

This metal is recorded as being known by the earliest society, and almost as soon as gold. In its native state it occurs in Huel Duchy and Huel Mexico, Cornwall, the mining districts of Saxony and Bohemia, but principally in Peru and Mexico. It is without savour or odour; the colour, a fine beautiful white, with a slight yellowish tinge, and brilliance equal to that of any other metal except perhaps polished steel; it is harder than gold, but softer than copper; its specific gravity in cast bars 10·474, in hammered plate 10·510; its malleability is only inferior to gold, and it is beaten into leaves only $\frac{1}{100,000}$ of an inch thick; its ductility allows it to be drawn out into a wire much finer than a human hair, so that a grain can be extended 400 feet; its tenacity in a wire 0·078 of an inch in diameter supports 187·13 lbs. avoirdupois. It does not suffer from immersion in the water; neither does it oxidate, although it tarnishes, in the air, at ordinary temperatures; but when raised to incandescence its brilliance much increases, and the metal fuses at 22° Wedgwood; during this state, in an open crucible, it solicits oxygen from the atmosphere, and becomes a greenish-brown oxide (Silver 1 + 1 Oxygen), and raised temperature causes the metal to boil and volatilise; but when in fusion, gradual diminution of the temperature renders the surface crystalline, and when this is congealed, by pouring out part of the fluid metal, may be obtained large crystals insulated, and in groups of four-sided pyramids.

Processes.—(1.) In nitric acid, at 12° Beaumé, dissolve 240 grains of standard silver; filter, add distilled water till the whole weighs 960 grains (2 ounces, or 1 silver + 3 aciduline solvents). This will cause the particles of the silver to be in a state so very comminute as to be readily, and without loss, separated in the precipitate. Stir well and often, with test 40, and leave it immersed 24 hours; when all the silver is precipitated decant the supernatant liquid, wash well the precipitate, boil it a few minutes in ammonia, to appropriate whatever spice of copper is present, filter, wash well on the filter, and evaporate dry, the *Pure Silver*. Or,

(2.) From a fresh supply of crystals form test 17, with which treat the nitric solution, and in 36 hours there will be a precipitate of sulphate of silver, with a superstratum of sub-oxysulphate of iron. This latter decant off, and separate all the muriate of silver presented by careful levigation of it in a solution of common salt.

(3.) To the nitric solution add lime-water, filter out and wash well the dark greenish-brown precipitate, which is without savour or solubilty in water; it is readily soluble in nitric acid, and at the proper temperature resumes the reguline state, or that of metal; dissolves in ammonia exposed to the air, and a brilliant pellicle forms, which, being dried, is the black oxide. Silver 1 + 2 oxygen.

(4.) *Chloride.* To the nitric solution add common table-salt until precipitation ceases; wash well this curd, and then evaporate dry. This compound is one of those least soluble, needing 3072 parts of pure water for solution. The action of the atmosphere causes it to gradually assume a purple tint. At a temperature of 500° Fahrenheit it fuses, and, on cooling, assumes the grey semi-translucent appearance called *horn* silver. The chloride is soluble in ammonia, and the result is fulminative; it is indifferent to pure alkalies, yet by carbonated alkalies it is solicited to separation, and any (but only) substances with hydrogen present will separate the chlorine. Silver 1 + 1 chlorine.

Only singular good fortune, and some skill of the operator, can always obtain the silver pure, and supersede failures from two causes: one, the uncertainty of the temperature; as when this is too high the chloride volatilises; and when it is too low there is not complete reduction. The other is, when high temperature is applied to this alone, the metal permeates the pores of the crucible and is lost. The easiest process is to use an iron pot, into which

put plenty of distilled water, a few pieces of iron, or fresh turned iron chips, also the chloride, and boil till all the silver is reduced. Some persons form a paste of the chloride and four times its weight of potash or soda moistened with water, and this is fused in a crucible well lined with alkali.

(5.) *Goettling's.—To separate Silver from Copper.* Determine the weight of the metal, as 1, and put it into a matrass; add test 24, 10, and water 5; keep in a high temperature of a sand bath, and frequently stir with a glass cane during three hours, then add boiling water, 6 bulks, continuing the heat; in a coarse linen bag put some clean copper turnings, which introduce into the matrass, and boil four hours; filter out the precipitated *pure silver*, and wash till the washings are indifferent to the alkaline potency of test 2; then reduce to a button, if needful. The liquid and washings evaporate till a pellicle appears, then crystallise the sulphate of copper.

(6.) Mix together glass powder 2, potash 1, nitrate of potash 2, and grain silver 8; this mixture put in a crucible twice the size usually employed for such a quantity, and over this invert and lute well a smaller crucible with the bottom perforated; place them in a furnace whose temperature will just fuse the silver; surround and almost cover the crucibles with charcoal; keep the temperature steady until a hot coal, held over the hole of the upper crucible, neither becomes more brilliant, nor causes a hissing noise; raise the temperature very high, quickly, and after 20 minutes take the whole out, cool, break the under crucible, and from the scoriaceous mass take the button of pure silver.

(7.) *Dize's.—To separate Silver from Gold.* When silver is present with gold, in twelve hours it deposits as a black muriate in the nitro-muriatic solution. In a platinum crucible, whose cover has a small perforation, add to the metal twice its weight of sulphuric acid, and raise the temperature to 180° Fahrenheit eighteen hours; then decant into a porcelain dish, and add two bulks of pure water, and let the fluid repose twenty-four hours or more. By siphon abstract the liquid from the brown precipitate, or gold, which throw upon a filter and wash with hot pure water. Into the decanted liquid immerse slips of polished copper, and when no more silver can be thereby obtained, as deposit or precipitate, wash it all well, and fuse it with charcoal in a crucible. The gold fuse with nitre, which separates the copper, and the solution of sulphate of copper evaporate and crystallise.

TIN.

This metal was well known at a very early stage of society, and, in more recent times, it was the Jupiter of the alchemists. So seldom has it been found, that its existence in a native or pure state has been questioned. As *Tin Stone*, or native oxide of Tin, which supplies most of the metal for commercial purposes, it occurs in primary rocks only, massive, crystallised, and disseminated, in veins; and when the texture is fibrous, the variety, found only in Cornwall, is named *Wood Tin Ore.* It is also found as a sulphuret, with a little copper and iron, called *Tin Pyrites*, of a yellowish-grey colour, with metallic lustre, fibrous or laminated texture, and prismatic irridescence. It is found in the mines of Bohemia, Saxony, the Isle of Banca, the peninsula of Malacca, Fahlun, the East Indies, Chili, and Massachusetts; yet in large quantity is it found only in Devonshire and Cornwall. Wherever it is found there certainly is plenty of it; but, comparatively, it is the most rare of the metals longest known and commonly used. Before any dates of authentic history, Cornwall supplied it, as the merchants of Tyre thence obtained it prior to the days of Moses, and in subsequent or contemporary times the Greeks obtained it from the ικτις or depôt on St. Michael's Mount, and by these it was supplied to any and all purchasers in the then known world.

Tin has a beautiful yellowish silvery-white

colour, and in its newly-formed state is very brilliant, rather impalatable savour, and when rubbed a very peculiar odour. The hardness of the mineral is between that of felspar and rock-crystal, and that of the metal between gold and lead; the specific gravity is 7·291, raised by hammering to 7·299. It has little sonorosity, but crackles remarkably when bended, and is very flexible; its malleability is such as to form beneath the hammer extended leaves called *Tin foil*, about $\frac{1}{1000}$ of an inch thick, and was it for purposes of commerce needed, might be reduced to less than half this thickness. It has less ductility and tenacity than any of the other seven usual metals; a bar $\frac{1}{4}$ of an inch diameter breaks by a weight of 296 lbs., and a wire $\frac{1}{10}$ of an inch just supports 47·20 lbs. avoirdupois; or according to Morveau, a tin wire 0·078 inch diameter just supports only 34·7 lbs. The atmosphere soon changes the brilliant lustre into a blackish-grey, which remains without further alteration from the weather, or immersion in water; but the action of very hot steam passing over red-hot tin quickly oxidates the metal, and the hydrogen of the steam is liberated. It fuses at the temperature of 442° Fahrenheit, and when slowly cooled crystallises into a rhomboidal prism. It resembles lead in being very brittle at a temperature of 380°, and when then broken by the stroke of a hammer, it presents a texture fibrous or grained. It is granulated by quickly agitating the mass during the time of its transition from the fused or fluid to the cold or solid state. Its purity is in exact ratio with its levity, while that of gold accords with its density.

Processes.—(1, 2, 3.) *Pure Grey Protoxide.* In hot muriatic acid dissolve grain tin; or in aqua-regia of nitric acid 1, muriatic acid 2, add only bits of tin in succession, one after another is dissolved, preventing loss from effervescence and raised temperature; the liquid alkalinise with test 1; the white precipitate or hydrate is partially re-dissolved, but the residue, left to repose, becomes a dark grey powder, with even a metallic lustre. The white powder heat to 300° to evaporate all the water, and the result is a dark grey oxide, without savour, soluble in acids and alkalies, and at 448° ignites and burns like tinder, becomes cream-coloured, and is converted into peroxide, which may be crystallised; and at 550° some of the oxygen evolves, and the metal is reduced. It also, when in solution, solicits oxygen from the atmosphere, and becomes the peroxide.

(4.) Expose the tin of commerce to a moderate heat in an open vessel; regularly skim off the surface the grey powder which forms successively; this impure powder afterwards keep at 400°, until all becomes the greyish-white protoxide, or *pure Tin Ashes*, an oxide more refractory in high temperatures than that of any other metal; and hence so useful in forming the opaque glaze of cream-coloured ware, and the white enamel.

(5.) *Berard's Method.* (*Pure Chloride.*) Into shallow dishes or saucers put the granulated Tin, and cover with muriatic acid, at 12° Beaumé; the offensive gas will be a compound of arsenic and hydrogen, and afterwards of hydrogen only; after 20 minutes pour off the acid into a vessel for subsequent application. The acid which attaches to the metal will continue soliciting it, hydrogen will evolve, and the atmosphere will promote oxidation. Pour on the acid again, and it will appropriate all the protoxide thus formed; and when a sufficient quantity of acid is employed, by pouring it off one portion of metal upon another, and allowing about two minutes to each, in succession, through the whole series, a solution of proto-muriate of tin, for making purple, is obtained very quickly and most economically.

(6.) To concentrated nitric acid add granulated tin, very carefully preventing loss by the ebullition while the temperature is raised; during the violent effervescence the tin, as a white powder, of *peroxide*, deposits at the bottom of the vessel, and assumes a very light yellow tint, when acid and water are expelled by

raised temperature. Another peroxide, with like properties to this, is obtained by distilling tin filings and red oxide of mercury.

(7, 8.) In nitric acid dissolve grain tin, precipitate by ammonia, filter; to dissolve most of the tin digest filter and contents in cold muriatic acid; again filter, and next dissolve filter and contents in warm concentrated muriatic acid. Add test 9 for any iron present. Or, in dishes (as 5) put tin filings, and cover with water 90, nitric acid 10, 48 hours.

(9.) In a tabulated retort, to muriate acid two parts add one of tin; slowly raise the temperature, and when the solution is finished add more acid and carefully decant into a well-stoppered phial; a black protoxide of copper is often left in the bottom of the retort.

The oxides of Tin have peculiar potencies in combining with other substances which they solicit, similarly, though with less momenta than acids. The peroxide does not dissolve in, but combines with, muriatic acid, and forms a compound soluble in water, as is that formed by the combination when digested with potash; and when the solution is evaporated a yellow jelly results, also soluble in water. With sulphuric acid, similarly to most metallic oxides, it combines into a compound not soluble in water, only the acid appropriates the water.

ZINC.

This metal has not hitherto been discovered native in Europe, and its reduction from the ore is of comparatively recent practice. The ancients, directed by the practice of Cadmus, formed brass by mixing with copper a mineral which had much zinc present; but they did not possess a knowledge of the reduced metal, which was first imperfectly described, about 1270, by Albertus Magnus, and the name was first used, in 1536, by Paracelsus.

The most common ore of zinc is *Blende*, a foliated brown unsavoury mineral, insoluble in water, with specific gravity 4°. The principal works for the reduction of the sulphuret are at Swansea and Bristol. The mineral is roasted, then pulverised and mixed with charcoal, and put into very large crucibles; these are carefully closed, the temperature is raised very high, the metal falls to the bottom of the pot, and escapes through an iron tube into a vessel of water, from which it is taken and melted into ingots, the *Speltre* of commerce, so much in demand for the brass foundries of the north.

Too frequently this is a mechanical compound of zinc, lead, sulphur, and charcoal, the last in a small proportion, remaining even after careful distillation; but when it has the specific gravity 6·861 to 7·1 cast, or 7·1908 hammered, it is regarded as best for the Arts. Zinc, in this condition, seems composed of many thin adhering plates, rather soft, with a brilliant slight bluish-white colour, unpleasant savour, and peculiar odour, and rubbed a little between the

fingers supplies a blue tint. Its little ductility allows it to be with care drawn out into wire, and its tenacity is that which in a wire of $\frac{1}{10}$th of an inch just supports 26 lbs. It connects the brittle with the malleable metals, differing as much from antimony and arsenic as from copper, lead and tin. The hammer renders it flatter, without breaking, and cautious, equal pressure reduces it to thin, supple, elastic plates, which break by folding.

At the ordinary temperature the atmosphere soon tarnishes but does not further change the surface of the metal, and a current of air seems needful to its slow oxidation; but when beneath water, soon is the surface black by the oxygen solicited from the water, leaving the hydrogen to evolve; with raised temperature decomposition is more rapid, and is yet further increased by exposure to a current of steam.

At the temperature of 220° it becomes malleable, and without breaking may be hammered into very thin plates; or, when this temperature has been long continued, it may be either passed through rollers, or easily turned in the lathe; and at 400° is pulverulent in a mortar; at 680° it melts, and slowly cooled forms masses of quadrangular prism crystals, disposed in every direction, which gentle heat renders a changeable blue colour; and at 750° it volatilises in close vessels.

Zinc melted in an open vessel soon solicits oxygen from the atmosphere, and covers the surface with a grey pellicle, which being removed is succeeded by another till all is oxidated into a powder without savour, insoluble in water, and useful as a water colour, but readily soluble in acids, forming neutral salts. When the results of the pellicles are

fused and agitated in an open vessel, soon is formed a yellowish-grey oxide. This projected into a crucible or deep pot at incandescence has a brilliant white flame, and emits *flowers of zinc*, very light and white flakes of oxide, zinc 1 + 1 oxygen, and this when spiced with carbonic acid is no longer volatile, but at a high temperature *fuses into glass.*

The reduction of oxide of zinc is difficult, because only by mixture with charcoal, and a long continuance of the temperature of a biscuit oven, or glass furnace, in a well-closed crucible, is diminished the momentum of its combinative potency with oxygen, and the prevention of its further energy.

That portion of Calamine with finer grain and texture than chalk, but otherwise much resembling it, is *Dicarbonate of zinc*, indifferent to carbonate of soda, but fusing with borax and phosphate of soda into a clear colourless glass.

Sulphuric acid with much momentum solicits zinc to combination, separating it from any impurity of charcoal, iron, and lead, during which hydrogen evolves, holding a portion of the metal in suspension, and which gas promotes the fusion of platinum, not effected by pure hydrogen. When the metal is in solution stir well with test 39, and any metals else will precipitate, and must be filtered out. If the acid be highly concentrated an opaque substance encrusts the bottom of the vessel, much like the German *white vitriol*, and less soluble than the crystals resulting from the solution. To the filtered liquid add test 3, filter, wash well, evaporate dry, mix with charcoal powder, ignite, and then with a white heat and porcelain retort distil into a receiver almost filled with water for *hydrate of zinc.*

Having in various and numerous instances detailed the manipulative processes of analysis, I shall only add, in concluding this part of the volume—that the more the student practises these processes, the better will he be acquainted with the usual phenomena of combination. He likewise will find that each resembles a chain, whose continuous links are the several steps of the detail. Aware that success in each depends and results from his first principles, from these he obtains the conditions of his demonstrations; and whenever incertitude attaches to any result, or however extended and operose may be the steps, he can at pleasure retrace each, or any part thereof, determine its validity, become more convinced on the one hand of the importance, and on the other, of the essential identity of legitimate results of these principles. The means of attaining sound knowledge is thus afforded, and I trust that as such each student will regard and employ them.

THE

CHEMISTRY OF POTTERY.

PART THE SECOND.

SYNTHESIS AND COMPOUNDS.

"Good Pottery differs from inferior much less in the number of its Components than in their proper proportions."—VAUQUELIN.

CHAPTER I.

HISTORICAL SKETCH OF THE ORIGIN AND PROGRESS OF THE ART.

THE Chemistry of Heterogeneous Compounds, because of its advancing several Manufactures essential to national prosperity, in importance has progressed with their extension, and the improvements in machinery during the last sixty years. The partial knowledge current having already accomplished much, we are warranted in assuming that the dissemination of further and correct information will promote additional improvements, more important than at present even conjectured, until the Manufactures are advanced to the perfection of

which each is susceptible. Only by its being pursued with vigour can we keep our country at its high eminence, nor subjected to receive from others that information which so long she has been accustomed to communicate. Still, to its peculiar investigation an inexplicable indifference has been evinced by the persons most celebrated as original thinkers or experimenters—the Daltons, the Faradays, the Henrys, the Brandes, while concerning those conditions of the component Atoms which ever remain the same, their observations have excited the attention of the scientific portion of the community.

The most obtuse intellect will admit that the kindling of fires, baking of bread, preparation of butter and cheese, smithery of metals, and burning of Clay into bricks, are Arts of Life coeval with their wants by the human family. These illustrate the development of man's physical powers to gratify his wishes, yet increase his comforts ; and they demonstrate that the primeval pair being created perfect in physical and mental powers, never at any time could all their descendants, the whole human family, possibly become the *mutum et turpe pecus*, the inhabitants of caves, the utterers of inarticulate cries, imagined by Diodorus Siculus, and others who have aspired to the dignified appellation, and sought credit for the high character of philosophers.

The Manufacture of prepared earths (which otherwise were valueless) into vessels of capacity, and different other subjects, for use, convenience, and ornament, of varied excellence of quality, and consequent difference of value, by adequate judges is regarded as useful, needful, and important to

civilised society, as any other Art of Life requiring the aids of human ingenuity. It is of importance to a nation, because usually the arcana of affluence to ingenuity, industry, and perseverance; one of the sources of productive employment, or excitements of taste and genius, of part of the population; a branch of commerce to increase foreign connections, supply correct ideas of political relations, and enrich the merchant; also a channel of revenue, to increase the power to preserve to the citizens their Rights from infringement, and their Liberties from subjection. It is most intimately connected with Chemistry, surpasses all others in facilities for comprehending Combination by processes of synthesis and analysis, and practising the Manipulations of the Laboratory. Its details involve numerous productions of Nature and Art; its developments essay to determine by what laws the reciprocal potencies of the component atoms, as well as the masses themselves, of those productions, by chemical changes cause different forms, as either a mere mass, or a beautiful regular and well-defined object. These forms it investigates and scrutinises the better to comprehend the nature and proportions of the components for interesting progressive improvements; to ensure excellence by the application of scientific principles; to benefit society by elevating the people in affluence, intelligence, and security; the vantage ground, whose occupancy and appropriation the Manufacturer owes to his country and himself.

Man in all ages seems to have been the resolute disavower of the authority of common sense, and the willing slave of his imagination. Yet the true

philosopher, employing the united faculties of a sound mind, also reasoning on the experience and attention to the operations of the senses as well as the perceptions of early life, to which he constantly and habitually refers whatever is new, whenever similar in any particular, by the powers of memory, feels delight alike elevating and interesting, in contemplating the immense Laboratory of Nature, directed by Omnipotence, whose fiat determines, with mathematical precision, the numerical proportions of Elements in which combinative potency can present the most varied and beautiful phenomena, from the constant reciprocal actions of gas, fluid, and solid, of acid, alkali, earth and metal.

The contemplation of subjects of human ingenuity leads the mind to regard the idea of commencement, and to reflect on the Inventor of an Art. Tradition and mythology have preserved the names of persons who deserve execration, because of the injuries they inflicted on their species; and some benefactors of the human race are immortalised in the poetry of the latter, but we fail to obtain data to identify the inventor of this art. Alike over the time and place oblivion has thrown an impenetrable veil. Certainly the probability of any traces of its origin reaching us without interruption seems precluded by the very early and long time prior to any historical records of its products (however rude and to our ideas uncouth) being formed and used. There is a possibility of its having, like many others of the Arts of Life, grown gradually into use, without any direct or sole inventor. The earliest sacred as well as profane histories mention it. But their writers, like

modern contributors to the stock of literature, frequently overlook useful and indispensable subjects, to dilate with ardency on the grand and pompous. In our day of universal spread of correct knowledge, whatever may have been the efforts, they have failed to shake the stigma of disrespect, by *Custom* irremovably fixed on the common and most useful Arts of Life—the Weaver, Tailor, Shoemaker, Smith; or to affect the importance attached, because of the value of the products, to the Jeweller, Goldsmith, Sculptor, and Artist, although in favour of the former may be the balance of moral worth against mean cupidity. We therefore may expect the person who had to record the *chefs-d'œuvre* of workmen "filled with the Spirit of God" (Exod. xxxv. 31, 36), to be indifferent to the productions of the Potter,* seen every

* The real primary force of the word POTTER (as well as its etymon, owing to the mutation of Letters in all adoptions of words into other languages) seems to be connected only with the Hebrew יוצר *yotsaar*, as employed in Genesis I. 24, 27, 31; II. 7, 19; v. 1, 21; to the *forming clay* into a human figure, and to the *formation* of the universe by the Omniscient Chemical Potter, the Infinite Master Mind. The idea of man's being earthy, and originally formed as vessels are by the Potter, or worker in clay; also the ease with which man, whether an individual, or a nation, can be "broken, even as one breaketh a potter's vessel, which cannot be made whole again," Jeremiah presents in his beautiful allegory, XVIII. 2-6. All those beautiful and elegant Wares, the most delicate and fragile, which quality some esteem as promoting its excellence in a corresponding ratio, or the most durable, which adorn our tables, manufactured with the same elementary components, processes, manipulations and general conformation; tortured from mineral substances by the agency of acids and temperature in the laboratory; most just in symmetry, chaste in design, exquisite in fabrication, fine in polish of surface, beautiful

day. Another reason why Moses does not even allude to the practice of the Art, and, by implication, to its inventor, may be the constant need for him to combat in the Israelites a proneness to idolatry. He must know that the Egyptian Pantheon consisted chiefly of persons who had conferred on mankind some general and lasting benefit; he was not ignorant who that people regarded as their instructor in this and most of the other Arts; and that to mention the inventor of POTTING would only again bring to their recollection the idolatrous worship of the individual, *Thoth*, or *Theuth;* Phœnician, *Taut;* Greek, *Hermes;* Latin, *Mercury*, the scribe of Saturn, the messenger (gr. αν γελος) of the gods, most assuredly a son or a grandson of Noah.

The solution of the problem, "*What kind of earthenware would be fabricated by a colony wholly ignorant of current processes?*" cannot be decided by

and splendid in enamel, rich, brilliant and tasteful in gilding, remain extremely liable by use to be broken and destroyed. Does any of my readers need to have the parallel presented before him? Man, however chaste in disposition, exquisitely sensitive, polished in demeanour, beautiful of feature, delicate in perception of propriety, graceful in motion, brilliant in imagination, rich in acquirement, tasteful in accomplishments; however finely modelled and finished and mentally endowed, his ultimate shows him—like the product of the potter—*earthenware!* The porcelain may be fractured and consigned to the sherd-heap, and in like manner may be deposited its fabricator and animated participator of the like earthy elements to the public cemetery or ceramicus.

"Whither the bodies of th' illustrious dead,
Are, by their friends, in solemn pomp convey'd."
WARD.

experiment, though almost by reasoning. All the Arts of Life, all useful Manufactures, originate in rude attempts to realise imperfect suggestions, or render palpable "some model in the master's mind." Invention is ever the daughter of necessity, and equally as much in our day influences the progress of Manufactures as in the earliest ages, when the general manners were simple, and the thoughts most busy to accomplish whatever might conduce to social comfort. Then, assuming that our colonised persons have intellects clear and energetic, with minds rational though uncultivated, the need to satisfy the imperative calls of appetite by conveying food to the mouth would quickly suggest the employment of some utensil, either shell of fish, or rind of fruit, as now practised in the country where the human family was first located, and by the negroes of the colonies and the aborigines of transatlantic countries. The preservation of articles of greater relish or refreshment, when plentiful, would suggest vessels to contain them ; and when the fermentative decomposition had caused alcohol to evolve, the quantity formerly taken would so affect the person's passions and reasoning powers, that in a state of ebriety men would again, as formerly, commit actions, related by historians, the subjects of regret during after-life (Gen. ix. 21. ; xix. 31-38). The pliancy and adhesive properties of Clay would readily suggest its employment for various purposes. The great facility with which Clay Wares can be made, the simple principles of the first manipulations of the workman, the importance of the articles, would induce different persons to endeavour to understand them ; and, as in

every other manual employment, the practice would cause improvement and excellence. Utensils so useful and readily fabricated would be subjects of desire to the ingenious, prior to the construction of the most rude dwelling; and though uncouth, compared with the productions of artisans bred up to the Manufacture, and with shapes to accord with difference of customs, and the usages of society, they yet would have form, size and strength, adapting them for their designed uses. Addition to the kinds, and improvement in the quality of the Wares, would ensue, because of the workman becoming more judicious in selecting materials, more dexterous in using his tools, and more intent on exerting his genius and inventive faculties. Correction of the exuberances of the design, and the ruggosities of the workmanship, agreeably to the suggestions of new arrangements, matured judgment, and refined taste, would promote shades of elegance, as well as accessions to the Manufacture. From such simple principles may have originated this Art, which in our day is so rapidly progressing towards perfection.*

* It is admitted that some tribes, descendants of the aboriginal inhabitants of America, and others resident in the islands of the Pacific Ocean, in skins and vegetable husks contain their oil and other liquids intended for subsequent use; and these are supposed to have suggested the hollowing of blocks of wood, or of stone, in which they immersed their food in water, and then caused the whole to boil by adding incandescent stones. Yet these preparations and vessels presuppose a knowledge of some manual arts, and possession of suitable tools. This filthy and inconvenient practice they reluctantly and with apparent self-denial relinquish, even after understanding that some earthy substances are refractory

There is no especial interest in the speculation, whether clay was appropriated *first* by the brick-maker or the potter; for even were this determined, our knowledge would remain as at present in reference to the time, place, and persons; yet both applications early were important and their productions in demand. When comfort and convenience rendered the erection of habitations indispensable, in their construction during a long period the chief materials were Bricks easily formed of clay, and merely dried in the air. The employment of clay for the purposes of the potter may have been suggested by mere accident, as the retention of condensed dew or rain, by some impression of the foot of an animal in the soft mass subsequently by the air rendered hard and dry; and its pliant and adhesive properties would show with how little labour it might be formed by the hand into different kinds of vessels. Although known much longer than the bricks now existing in Rome, and made more than 3000 years ago, yet no such ancient specimens of earthenware remain. Egyptian bricks and cinerary urns, even though indisputably authenticated as of long prior date, would fail to determine the question of previous appropriation, or to support the proper claim to antiquity of invention.

The different portions of the human family, wherever located, would experience like wants, and

in the flame; also, that however useful fire may be in preparing food, disadvantage would follow its application to the vessels of wood and skins of animals, which by it would inevitably be destroyed.

originate similar Arts of Life; and readily would they embrace opportunities to gratify the one and practise the other. And as those tribes of the family, in different regions, who retain merely the civilisation of the first ages, possess some knowledge of this Manufacture, I feel persuaded that its practice must have prevailed previous to the migrations of the post-diluvian tribes, and long anterior to the expectation of results so elegant and complicate as porcelain and flintware. The recent discoveries of travellers in the transatlantic continent prove this, from a period most remote, in portions of the globe, where not even imagination had suggested that its productions were known. The *American Archæologia* supplied numerous notices, a few of which I shall insert, prior to the continuous detail of well-determined historical facts.

Being accustomed mentally to connect with the idea of this Manufacture the associations of a series of buildings for the different consecutive processes, there might be some difficulty in obtaining for the statements that ready credence, even by intelligent and impartial readers, which they deserve, did we not suggest the great probability, that these potters, and others of the very early practisers of the Art, pursued their operations in a manner something similar to that for the Manufacture of glass in the present day adopted in Bohemia: The tribe of artisans having found a suitable stratum of clay for the bricks of the furnace, near a wood, commence operations by cutting down timber in quantity sufficient for erecting their habitations, sheds, workshops, and warehouses; next they quarry the clay, make

the bricks, burn them thoroughly with the chips from the timber, erect the furnace, and, for fuel, cut down whatever quantity they need; also burn brush-wood to prepare the alkali for the Manufacture. Here the artisans remain located, until in the processes all the wood has been consumed.

The aboriginal inhabitants of Maypure, in South America, and of Florida, are celebrated for their Manufacture of a species of Delft ware, of excellent quality, on which are ingeniously figured and correctly painted, birds, monkeys and crocodiles.* These specimens of workmanship of ancient Indians, in many properties equal, if they do not excel, those of modern European fabrication. During the presidency of Mr. Jefferson, persons employed in digging at Palmyra, on the river Tennessee, discovered and delivered to him various busts, of whose fabricators no other traces remained, though conjectured to be progenitors of the present race of Indians. The figures are almost of the natural size, to below the breast, and present good resemblances of the head, face, neck and shoulders of persons unrecorded in

* "To form figures or impressions of particular subjects on plastic clay would be early practised by the first potters, and is the most probable origin of all our boasted arts of sculpture, painting, hieroglyphic design, writing, seal-engraving, and ultimately of printing, and copper and steel-plate engraving. How interesting is the series to the contemplative philosopher! And each Manufactory may have continued to imitate the approved ornaments of its preceding owners, till we trace the patterns used by the most early nations, when just emerging from their state of hunting for daily food."—Sir R. Phillips (*Walk to Kew*, p. 300).

tradition, but the well-executed features delineate the physiognomy of the American copper-coloured Indians. The countenance of one has most distinct traits of the wrinkles of thought and age. But whether objects of idolatrous worship, or mementos of the country's most distinguished sons, remains to be determined. I am not aware that any attempt was made to ascertain whether their hard black substance, analogous to Wedgwood's *Egyptian*, was a natural or an artificial production, and consequently, they the work of the sculptor, by the labours of the chisel, or of the potter, first modelled and then baked. But the latter is the more probable, and accords with the object of mentioning their discovery. In Lord Hilsborough's cabinet are two Indian vases, obviously very antique, found on the shore of the Mosquito River; and, when mentioning the discovery of very ancient potteries high up the Black River, Governor Pownall thus describes these vases: "It is a decided fact, that they are curious exemplers of some of the first efforts of human ingenuity, and remains of what are become antiquities even among the Indians."* Father D'Acuina asserts, that by some of the Indian tribes located on the shores of the river Amazon, in South

* Roylance Child, Esq., my neighbour, recently deposited in the museum of E. Wood, Esq., Burslem, a beaker, or ewer, of this Manufacture. The colour is brownish-red, the design beautiful, the form that of a very tall turned cream-ewer of our artisans; the weight very light compared with porcelain, and a size or varnish employed in place of a glaze. I examined it very attentively, and the preservation of the fine lines, the absence of seams, its extreme lightness, and the *tout ensemble* induce the opinion that it has been *cast* with a clay which does not need a glaze.

America, this Manufacture has been pursued from an era long anterior to any historical record, to all the extent needful to supply the demands of neighbouring nations, with whom they had established a regular traffic. The Indians of Louisiana at this day fabricate very durable ware ; the clay or body is compounded of what is commonly so named, with which they mix certain proportions of calcined crystallised felspar from granite ; and the vessels will bear any temperature for culinary purposes, while the seggars and crucibles will sustain the highest needful for their furnaces and ovens. The vicinity of Salem, on the Lake Erie, presents extensive remains of ancient potteries. The opening of some burrows in Ross County has supplied antiquarians with two covers of vessels, fabricated of either marble, a calcareous breccia, or *terra cotta*, which for all valuable properties and excellence will bear comparison with any by Italian artists now produced of similar materials. Several earthen vessels were obtained, which adequate judges regard as equal in quality and workmanship to any present productions of the art. At Marietta, in 1819, were found specimens of ancient earthenware, which in excellence and the exhibition of attention to neat workmanship, are not inferior to any productions of the present race of Manufacturers. They seem to be compounds of clay and pulverised flints ; and they still remain completely firm and solid, though long exposed to all the alternations of the atmosphere, prior to being preserved in a museum. Others are less compact, dense and firm ; and only partially, if at all, baked ; and they seem compounds (like the ware fabricated by the Indians)

of clay and pulverised clam shells. All the specimens to which these remarks refer, display those proofs of persevering industry and genius during the progress of the Art, with manipulations simple and common, of which only inadequate ideas will be formed by persons ignorant of the processes.

The authority of sacred history supports the assertion that B.C. 2200 years, and 500 years prior to the migration and settlement of Jacob's family in its territories, the kingdom of Egypt was in great prosperity; and its people, blending fact with fable, as previously mentioned (p. 368), claim a very early practice, and also perfection in the processes of this Manufacture and that of glass. Siracides remarks that covering earthen vessels with a crust of glass is an ancient practice, which has recently been fully corroborated by the indefatigable Belzoni; who says, "the art of varnishing and baking the varnish on clay was in such perfection, that I doubt if it could be imitated at present."—*Researches*, p. 173. The quantity of vessels by this people required is not of importance; but it would extend with the demands of the population to contain supplies of oil, juices of fruits, water, etc., and the ease and readiness with which could be acquired by the workman proficiency in its processes, and dexterity in its manipulations.*

* Herodotus could not possibly be ignorant that Egypt and Phœnicia were old nations compared with the Grecian states, which received their *arcanum alphabeta* from a Phœnician, and whose sages visited Egypt to acquire correct acquaintance with the knowledge current in their day. He incidentally notices the scarcity of earthen vessels among the Greeks, and yet seeks to

In building the Tower of Babel (Gen. xi. 3), there were used bricks "burned thoroughly;" and

flatter their vanity, and indulge their prejudices, to augment their celebrity, by making them potters for all Egypt and its dependencies. "Twice in every year there are exported from different parts of Greece to Egypt, and from Phœnicia in particular, wine, secured in earthen jars, not one of which jars is afterwards to be seen, for the principal magistrate of every town is obliged to collect all that are imported to the place where he resides, and forward them to Memphis. The Memphians fill them with water, and afterwards transport them to the Syrian deserts. Thus all the earthen vessels carried into Egypt, and there carefully collected, are continually added to those already in Syria."—Book III., Sect. 6th. The natives of the interior of Africa accomplish their passage across small streams by securing each end of a stout pole to a large gourd; and seated across the floating pole, with a second pole the passenger forces himself across. In some parts of the East the ferry-raft, or *Charpoy*, is formed of stout framework of bamboos, not unlike a set of bedsteads, and secured together by net-work of cords which support the cargo. Beneath the posts and rails are inverted and well-fastened beaker-jars named *Kogerii*, in which is compressed such a quantity of air as renders buoyant the whole, which is readily pushed through the water by the ferryman. A practice somewhat similar seems to have obtained among the Egyptians in the days of Juvenal, whose surprise seems excited by the singularity of the danger from obstacles which might be encountered, in fine weather, and the vessels being dashed against each other by the gale. These rafts he names *earthen-boats*.—Sat. xv. 126-128.

"Hæc sævit rabie imbelle et inutile vulgus,
Parvula fictilibus solitum dare vela *phaselis*,
Et brevibus pictæ remis incumbere testæ."

The *earthen-boat*, alone, through dangerous tides,
With wild and vulgar ruthlessness he guides;
Or else reclining on his *painted shell*,
Its short length paddles through the briny swell.

we may suppose their use well known in Egypt from the great quantities required (the remaining specimens of which excite our surprise because of their durability) before the ingress of the Hebrews (B.C. 1706, Gen. xlvii. 11), and the rigour with which, from this people, the taskmasters exacted the tale until the Exodus. Will it be too great an assumption

Dr. Harmer (vol. I., p. 90) mentions that Upper Egypt supplied the Delta, or Lower Egypt, with sufficient for all purposes of home consumption and exportation. The potters were aware that the porosity of the vessels in biscuit state, permeated by water till almost filled, might cause the raft to swamp; therefore they covered each with varnish (by us called *glaze*), and connecting them as a raft or float, sent them down the Nile to Memphis. The great frequency of the practice proves that not a small number of jars would be required, and diminishes the probability of Greece affording the supply, as Herodotus insinuates. Indeed, I think the country where the practice obtains must have known little of Greece or her customs, else these last would have suggested the use of boats of more buoyant and less fragile materials. "It may be proper to observe (says Harmer) that these floats are not constructed to pass up and down the Nile like boats, or designed to carry goods upon them, though they may occasionally be put to that use [as during the time of roses blowing, for making rose-water, in profusion cultivated at Fiume, beehives are brought on such rafts, and when the flowers are decayed, the hives are returned to their owners]; it is only an easy way which the Fellahs discovered, and by their descendants observed, of conveying their earthenware from Upper Egypt, where it is made, to the Delta, or lower part of the country, where, on its arrival, the float is taken to pieces, and the vessels are sold to the inhabitants." Norden, the doctor's authority, also states (*Travels*, vol. II., p. 75): "To cross the Nile, the inhabitants of Upper Egypt contrive a float made of large earthen pitchers [jugs] tied closely together, and covered with leaves of palm-trees; and the man who conducts it has commonly in his mouth a cord, with which he fishes as he sails along."

that the fabrication of bricks would introduce also that of vessels? In Egypt this people learned many Arts, which they practised after their emancipation. The products of this art are often mentioned by Moses (Lev. vi. 28, Num. v. 17), and while they imply that he was acquainted with their usual mode of Manufacture, I think we should ill compliment that numerous and intelligent people, by the supposition that this knowledge was exclusively possessed by their leader. Neither ought we to conclude on the non-existence of potters among them because they are not specially mentioned. That wares formed of clay, whether we call them pottery, porcelain, or earthenware, were in request, and of excellent quality, prior to any historical mention of their use, is clearly proved by the beautiful specimens which are usually discovered deposited with the mummies, and coeval with their existence. These with beads have been found, and even vessels, covered with a rich glaze of a blue colour; and pieces of blue enamel, much similar, have been found in the tombs at Thebes. Mr. Delaval applied tests to a portion detached from a small image found with a mummy to ascertain the colouring materials, and was of opinion, that upwards of 2000 years anterior to the employment of chemical investigation to such subject, there existed accurate knowledge of the virtue of oxide of cobalt to give a beautiful blue tint to any vitrified chemical compound of silica, alumine, and alkali, though this was applied for this purpose only since the early part of the eighteenth century, A.D. That iron was therein employed recent facts fully prove. As specimens show their having been

thrown on the "potter's wheel," it must have been used in Egypt for the purpose. The most authentic records mention it; Homer, as well as Moses, regards it as very ancient in his day.*

The Canaanites of holy writ among their branches had the most distinguished merchants and most celebrated philanthropists of that era, the Phœnicians. In their commercial migrations they either supplied colonies, already established, with the Manufactures then current, in the way of barter, or placed their countrymen, with adequate knowledge to pursue whatever branch might seem best adapted to the locality. They are admitted to have been well skilled in the processes requisite for manufacturing excellent earthen and glass vessels. Of the site of their own potteries history fails to inform us; yet although the two cities Tyre and Sidon were the marts most noted, of their being the seat of the Manufacture there is not the least proof; but from them, more than 1200 years before the

* The "magic of a name" is here obvious. The invention of the potter's wheel Strabo assigns to Anacharsis, the Scythian (or Gothic) philosopher, and is followed by Seneca, Suidas, Diogenes, Laertius, and others, whom it were insult to suppose ignorant of the wares supplied by Tyre and Sidon, marts when Athens was mere hovels. Pliny (lib. xxxv., sec. 14), on the authority of Diodorus the Sicilian (iv., 319), asserts that the alleged inventor brought it from Scythia. This personage was otherwise named Icarus, the nephew or grandson of Dædalus, the architect, in the days of Solomon; and probably, after completing his travels in search of information, he might benefit the Greeks by communicating the model of the machine. The date of the assigned invention is more than 1000 years later than its known use, consequently will not support the allegation.

advent of the Messiah, most ports of the then known world obtained supplies. No doubt can arise that they would select the situation most suitable; and as the vale of Chozeba in subsequent times (the valley of the Son of Hinnom, very probably a noted potter, and maker of the *earthen-gods* which so abounded through the idolatrous portion of Jacob's family, 1 Chron. iv. 22, 23, was the site of the Jews' potteries, and is remarkably placed for connection with Tyre, Sidon, Joppa, and Jabneel, I suggest the probability, that there the Phœnician potters were employed, and that the Manufacture was continued for the special advantage of the Jewish kings after the conquest.

The Phœnicians also excelled in the fabrication of figures of remarkable persons and objects, so much demanded to ornament their groves for licentious rites and ceremonies, and which so greatly promoted idolatry, that divine displeasure annihilated many of its votaries.*

* Pliny quotes Praxiteles for the authority, "that *figulus primus inveniit ex argilla fingere similitudines;*" and in the art of modelling clay the progress was more rapid, and the improvement greater, than in any other, because of the facility with which it was accomplished. The historian (lib. xxxv., c. 12), not aware that there existed specimens of earthenware figures, now acknowledged to have been employed in decorating Egyptian mummies many centuries prior to the date of the introduction of potting into the State of Corinth, gives the following pleasing anecdote to prove the origin of sculpture in the strongest emotions of the mind, and also to establish the claims of the Greeks to the merit of the invention; not that I wish to question the accuracy of the statement as connected with the parties mentioned, only that, previously, others had practised the art: "A celebrated potter of Sicyon had a beautiful daughter, named DIBUTADES,

The Phœnicians, according to Strabo (I. 3), at a very early period visited Britain for tin, not then known to exist in any other country, and during many ages supplied its inhabitants with vessels of earthenware and glass. There are in holy writ references to our country as one of "the

who, with her father's approbation, had encouraged the attentions of a sailor, occasionally absent for some time. On returning after a rather protracted absence, he was indulged with the favour of a private interview, during the hours when her father was at rest, ignorant of the assignation. The lover had been much fatigued at his return, and the detail of incidents to his beloved prolonged the interview until sleep overpowered his senses as they sat by the midnight lamp. The reflection of his features by the rays of light strongly marked the profile on the wall, and the watchful fair one thus had her attention directed to the means of securing the likeness of her lover as an object of regard during his absence. With the end of a half-burnt stick as a stile, she quickly traced the outline, no doubt so truly in accordance to Nature that memory would readily supply all the features omitted. The father afterwards noticed this sketch ; he applied clay to the outline, filled up whatever was requisite, and in a short time produced a correct likeness of the face for his daughter's constant notice when the idea of her lover presented itself. How must this modeller have been gratified while proceeding: the mere lump of clay assumes a reality of figure, to which each point of view suggests additional modification by the tool ; to the daughter all is real, tangible, and needs only vitality, which the imagination is ready to supply, as she gazes on the lips inviting her salute ; and witnesses how, agreeably to the simplicity of truth, symmetry secures the just proportions of form and size, and the perfect lines of ideal beauty. And at a period not later than the eighth century before Christ this clay figure suggested the kindred practice of casting, and the now more esteemed art of sculpture. This production, regarded as the first essay of the art in Corinth, was long preserved in the public repository, but was destroyed by the foolish and barbarous Mummius Achaius, when he sacked the city. Those which Solomon established in the vicinity of his capital to indulge his wives and concubines (1 Kings xi. 3, 7, 8), and in imitation of which other kings also

Isles of the Gentiles," and to the metal tin, Gen. x. 5, Num. xxxi. 22, 1 Kings x. 22, Ezek. xvii. 4, of the respective dates 2200, 1460, 1000, and 600 years B.C. The mention of the metal in the *Iliad* proves its use prior to Homer's day. Many writers mention the statement, that from Tyre and Sidon the Phœnician sailors, in their trading vessels, visited, for its tin, the land of On, Britain, at least 285 years before the birth of Moses. (See Cellarius, p. 15; Cesar, 186,

established (xiv. 23, xvii. 28-33), probably suggested the *ceramicus* at Athens; the shining whiteness of the figures suggesting the application of the word to wax-work, and giving the name to the spot where figures of the "illustrious dead" were placed over their graves.* The kings of Judah, from base motives, either encouraged or winked at the proneness to idolatry which supplied funds for their luxury; and as statuary marble was introduced only in the eighth century before the Christian era, and numerous statues had been erected in different groves, etc., long previously; and, when certain monarchs had cut down these, others who succeeded had fresh images supplied, set up; may not the expression, "to pass through the fire," regard as much the potter's process of baking figures of the objects of idolatrous worship, as of sacrifice of the person mentioned. (See Wisdom of Solomon, xv. 7, 13, 15.) The "Potter's-field" was a public cemetery, and we have no proofs of its being the *ground* where they *wrought tygs* (vessels for drink), as the Saxon "*æcer tigel wyrhtena*" implies.

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* In the Ashmolean Museum, Oxford, is preserved an excellent specimen of ancient pottery, on which, in its natural size, is the face of a beautiful woman, whose physiognomy completely differs from that of the Greeks. It is fully described, page 1017, vol. xv., *Phil. Transactions*. Of the productions of these early Phœnician potters, most excellent specimens from excavations under the city of Acre, in great numbers, of vases and other vessels, are now preserved in the museum of the Baron Judica, at Calazolo, all of which are long anterior to the Christian era. And of the value attached to some of these specimens an idea may be conceived, when I state, that in the Scudi Palace, Naples, are numerous specimens; and among the cinerary urns is one for which the king of Naples paid 10,000 piastres, or £2,200 sterling.

204; Arist. De Mundo, iii. 614.) Wherever this people introduced articles of commerce, they ultimately established Manufactories; and in the *Philosophical Transactions* (xix. 319, xxii. 564) are mentioned vestiges and even sites of extensive potteries in different counties, where scarcely imagined probable; and which plainly indicate, that in those places operations had ceased long anterior to any authentic records. Because of either some peculiar sentiment of respect, or regard to the long-cherished doctrine of the body's resurrection—or its bastard offspring, transmigration of the soul—with the corpses of important personages were deposited in sepulture vessels containing spices. And which custom is the cause of the numerous specimens of earthen urns, beakers, and bowls, which at different periods have been obtained when opening barrows in several parts of the kingdom, rude in formation and deficient in taste in regard to ornament, but not the less interesting from those qualities. They are regarded as objects of peculiar importance, because, having been found in situations which they must have occupied many centuries prior to the Roman invasion, they establish the fact of the ware being used for different purposes. And because their origin is incontestibly not Roman, the difficulty is attempted to be superseded by making them Venetian, though Venice, even if it were anterior to Rome, was not then known *to have potteries;* and there is much probability that by mistake the name has been substituted for *Phœnician*, which people had ceased, soon after the time of Solomon, to be the general merchants of the then known world, and could not have supplied all parts of Britain, except at very great risk of loss and damage.*

* In the *Archæologia* (282, etc.) is reference to others obtained from a British pottery, long submerged beneath the tides of the sea. In the cottages of the fishermen near Margate Roads are frequently to be seen earthen vessels, of rude workmanship, and coarse materials, which have been obtained from the nets at various times thrown on a shoal (because of these vessels called the Pudding Pan Sand), about two leagues from the shore in

The Phœnicians, unable or unwilling longer to endure the intolerable exactions of Solomon, whom they had benefited in numerous ways (1 Kings ix. 21), and there being great probability of additional bond-service (B.C. 1000), a colony of potters and other artisans emigrated from Tyre, across the Mediterranean Sea, to the foot of Mount Vesuvius, and at Nola commenced their Manufacture of earthen vessels, and continued it, with a dexterity of workmanship, and with such taste in shapes and ornaments, and a high state of excellence, elegance and perfection, as have scarcely yet been equalled; and obtained from the rulers of the country, and subsequently from the Roman government, in behalf of the artisans, every possible encouragement. Pliny, where already quoted, mentions that Numa formed into a seventh confraternity the potters, who at a later period assumed the name of Etruscans. But although it does not appear clear whether this was applied to them for distinction from others, who had separated and commenced the Manufacture in other places,

that part of the Margate Roads called the Queen's Channel, near the mouth of the Thames. Upon the greater number of these vessels, adapted for the rites of sepulture and other religious ceremonies, is very neatly impressed the name ATTILIANUS, and also upon fragments, finer in quality, but less durable, and very rarely regarded as worth preserving, because of no use. The opinion prevailed that here had been sunk during the time of the Roman domination a trading vessel, whose freight of earthen vessels was now being obtained from the deep, in which they had so long time been immersed; perhaps because the currents had carried away the timbers of the vessel. But this opinion was proved illusory by some nets bringing up *bricks* of Roman fabric, well cemented together. In 1778 more research ensued; Ptolemy's Geography was examined, and in his second book, reference is made to a small island at the mouth of the Thames, as existing two hundred years anterior to the visit of the Romans to Britain, and in that particular part where now is the shoal, but which island is not mentioned by Cæsar, and is, therefore, supposed to have been submerged prior to his ambitious invasion of this country. The conclusion drawn by Governor Pownall, is, that upon this island was once a pottery, and that it was either owned (most probably) or managed by the person whose name is thus singularly preserved to our day. This mode of fixing the name suggested the practice to WEDGWOOD, and is continued by his descendants, and adopted by many others in the present day.

especially at Arezzo and Faenza (whence probably *fayance*, the French name for earthenware), it is not to be controverted that from here went the potters to Corinth, which city afterwards became celebrated for the excellence of the ware made by the potter Demaratus, B.C. 600, and who afterwards left his Grecian connections for the more celebrated and convenient potteries of Italy.

Very early were the Persians celebrated for the Manufacture of porcelain, if we credit Propertius, who wrote in the time of the Emperor Augustus, and as quoted by Sir John Chardin. Dr. Harmer boldly asserts (Vol. I., 74, 5), that the best Asiatic porcelain is that of Persia; and he mentions principally Shiraz, the capital of Persia Proper; also Metched, in Bactriana, and Yesd, Kirman, and especially Zorendi, in Caramania. There is also a tradition, that on one occasion the potters at Yesd sent to Ispahan, in defiance of those in that city, a porcelain vessel, of twelve pints content, yet its weight only the eighth part of an ounce (probably *pound;* for a sheet of paper of the like size would weigh a drachm).*

* The following anecdote will prove that the Persians are aware of the excellence of their productions, and how easily, for their home supplies, the Dutch may mix it with the porcelain of Nankin: In 1666 the Dutch ambassador to the court of Persia was exhibiting the many rich presents he had brought for the reigning prince, among which were fifty-six pieces of very valuable Chinese porcelain. These the prince viewed with contempt, in derision inquired what they were? and on being informed, laughed most heartily at their non-importance, to the very great confusion and mortification of the ambassador. Unacquaintance with these facts is the probable cause why Robertson, with a good intention, no doubt, supports the attempts of the Abbé le Bland and M. Larcher (*Mem. de Litterat. XLIII.*), to prove that the very valuable vessels mentioned by Pliny (xxxvii. 2), as brought from Pontus, B.C. 64, by the victorious army, and first seen at Rome at Pompey's triumph, and called *vasa murrhina*, *murrina*, and *murrea*, were formed out of a transparent stone, dug from the earth in some of the eastern provinces of Asia, and by some persons called Parthian *agates*, whitish, but variolated. These writers do not assign any probable cause for the number found together being of the same kind and quality; neither do they state where similar stones are now to be found, nor supply any slight traces of the practice of fabrication; and yet

The opinion entertained by persons (whose education has led them to suppose that the Romans taught the Britons all the Arts of Life) of this Manufacture having originated with the conquest of this nation by that unprincipled and ambitious people, I feel bound to show devoid of solid foundation. I will admit that in the vicinity of some of their military stations have been discovered remains of small potteries; and that bricks, 17 by 11 inches on the surface, and $2\frac{1}{2}$ in thickness, remain in the walls of Verulam, a little south of St. Albans. Also, that in Hyde Park were dug up, in the beginning of the eighteenth century, water-pipes, 2 inches thick, and with their joints formed of common lime-mortar moistened with a vegetable oil, and assigned to the Romans, because Vitruvius mentions water-pipes fabricated of potter's clay. But, as amulets (*glain neidyr*)—about half as wide as the finger ring, but much thicker—of glass, usually of a green colour, but others blue, and wavy of red, blue, and white, used as a charm for the vulgar, are yet preserved entire, which were manufactured by the British Druids many centuries anterior to the Roman conquest, before I concede every relic of ingenuity to that people, some indisputable authority must convince me that among the Britons had ceased to exist

we cannot suppose that there would be entire loss of a Manufacture (which for excellence of workmanship required and manifested considerable judgment and dexterity) in the country where such valuable stones were quarried. Had these writers just attended to the geography of the country, they would have seen the great probability, not merely that the vessels were of eastern Manufacture (as they seem to admit), but that they were indeed Persian porcelain vessels, and in quality similar to those used in the time of those great scholars, Cardan and Scaliger, both of whom entertain this opinion, though seldom on any other agreeing. There is close approximation to the facts also in their speculations, from the statements of travellers, on the component materials of the vessels: "they were formed of eggs and sea-shells, marine mollusca, beaten small, and buried from eighty to one hundred years;" as the fluid mass of the preparing clay is not unlike beaten eggs, and the long deposit of the mass underground is even in our day a practice in China.

all that native genius which had in prior ages enabled them to confer inestimable obligations on Greece as well as Rome; for we have these authorities—Gobryas, the Persian, Hellanicus, a writer long prior to Herodotus, Socrates, Plato, and Diodorus Siculus, that our ancestors sent, in Phœnician trading-vessels, to Delos, three virgins, with tables of our copper and tin, or copper and zinc, on which were written the doctrines of religion, especially concerning a future state of retribution, the blessedness of the just, and the misery of the wicked. Also, that the colonisers of Britain, long before Rome was even a range of sheds, or dignified with a *name*, were not incited by the utility of domestic utensils, the plentiful supply of materials, and the facility with which they could be fabricated, to render themselves expert in providing substitutes for those destroyed by accident or using. Also, that Verulam was of Roman erection, and chiefly occupied by that people's legions. Also, that such water-pipes are not of Staffordshire Manufacture, where from periods long prior to any historical records, clay for the purpose has been quarried to an extent, proved by existing excavations, after long being receptacles of potsherds, etc., only to be credited by persons who inspect them. Besides, the opinion presupposes, that among the legions were persons who greatly excelled, and had plenty of time which they could and did employ in the Manufacture; also, that much earthenware was used by the armies; and further, that only the most rude specimens are preserved to posterity. With about equal propriety might I assert that Knut, the Dane, established the Manufacture in Staffordshire, now so flourishing, as the staple of the borough of Stoke-upon-Trent. For there is an equally indisputable fact, that at one of his military posts, Cæsterton on de Ieam) *Chesterton-on-the-Loam*, one extremity of Knutton-heath, and only two miles distant from *Knut-Castle-on-the-Loam*—through the errors of copyists corrupted in modern orthography to *Newcastle-under-Lyme*), at the depth of 7 to 10 feet below

the surface, the late Mr. Josiah Wedgwood and some friends discovered appearances of an early pottery, such as we might imagine would be presented by the borough of Stoke-upon-Trent, was it to be submerged, and at the expiration of many centuries were to be again exposed, the foundations and remains of workshops, ovens, masses of potsherds, and other refuse from the vessels injured by baking.

In the chapter already quoted, Pliny mentions the usefulness of clay, "in yielding us the conduit-pipes for water, also tiles, flat or hooked, or made with crotchets at one end, to hang upon the sides of the roof, or chamfered, to form gutters for the flow of water, or curbed for creases to clasp both sides of the ridge, besides the vessels which are turned with the wheel, and worked round; yea and large earthen tuns and pipes, constructed to contain either wine or water." Also, "Vitellius, while he was emperor, caused a charger to be made and finished, which cost a million of sesterces [if so, £8,000 sterling; but possibly an error of the copyist for a less sum], for the baking of which a furnace was purposely erected."* There is additional

* In accordance with this mode of erecting a furnace expressly for a particular object, I find the following statement by Plutarch, in his life of Publicola: "Tarquin, while yet upon the throne, had almost finished the temple of Jupiter Capitolinus, when, either by the direction of an oracle, or upon some fancy of his own, he ordered the artisans of Veii to make an EARTHEN CHARIOT,* which was to be placed on the top of it. Soon after this he forfeited the crown. The Tuscans, however, modelled the chariot, and set it in the furnace; but the case was different with it from that of other clay in the fire, which condenses and contracts on the exhalation of the moisture, whereas it enlarged itself, and swelled till it grew to such a size and hardness that it was with difficulty they got it out even after the furnace was dismantled. The soothsayers being of opinion that this chariot betokened power and success to the people with whom it should remain, the people of Veii determined not to give it up to the Romans, but upon their demanding it, returned this answer: 'That it

* A remarkable corroboration of the opinion I have given, p. 381, of the employment of the Potter's Art for objects scarcely accomplishable by the labours of the sculptor.

support to Pliny's statement in the translation by Wickes Skurray of the Marquess Don Marcello di Vinuti's Account of the Discoveries at Heraclea, in Pontus, published in 1750. He says (p. 110): "Through a door of white

belonged to Tarquin, not to those who had driven him from his kingdom.' It happened that a few days after there was a chariot race at Veii, which was observed as usual, except that as the charioteer who had won the prize and received the crown was gently driving out of the ring, the horses took fright without any visible cause, but either by some direction of the gods, or turn of fortune, ran away with their driver at full speed towards Rome. It was in vain that he pulled the reins, or soothed them with words; he was obliged to give way to their career, and was whirled along till they came to the capitol, where they flung him at the gate called Ratumena. The Veientes, surprised and terrified at this incident, ordered the artist to deliver up the chariot". Allowing that the expense was borne by funds supplied by the emperor, I cannot but suppose their processes, as well as materials, must have differed greatly from those of other potters of the Roman era, as well as from those of our own artisans of the present day, dependant on their own industry, genius and capital. In the *Archæologia* are Remarks on Roman Antiquities of the Durobrivæ of Antoninus, with correct figures of the subjects now to be mentioned: At Castor, Northamptonshire, Mr. E. T. Artis discovered, in a state of complete preservation, the Biscuit and Gloss Ovens, which were portions of a Roman pottery, with vessels therein, as they were placed for baking, and remained while and after the town was destroyed by conflagration. Both ovens will not compare with those in present use in magnitude. The Biscuit-oven can scarcely be called conical; the diameter at the bottom is 4 feet 6 inches, and at the top 5 feet, and its height is 4 feet. From the hearth, at 18 inches, is a floor of triangular tiles, 3 inches thick, with their points resting on a pillar in the centre of the fire-chamber (or receptacle of the fuel, supplied through an aperture in the front); the broader end of the tile is perforated with two circular holes, an inch in diameter, through which passed the flame to bake the vessels in the upper chamber, or oven, 2 feet 3 inches deep. As only red pottery was found in the oven, and no trace of seggars (certainly not required for such ware), we have no proofs for or against their use. Also, whether the sides were higher or not is not determined, nor the manner in which it was covered; but probably a conical arrangement of flat tiles was employed for this purpose. The Gloss-oven is formed of two hemispherical muffles or seggars, 2 feet 6 inches diameter, together ranged behind the biscuit-oven, and by a large rim or flanch suspended over the fire-chamber, similarly supplied with fuel through an aperture in the front, and beyond the hindmost seggar was another aperture for the smoke to escape. On each seggar fits another, almost hemispherical and rather longer. Both were half filled with wares in the last stage of their Manufacture. Professor Haussman has proved that the ancient vases were

marble we entered a room, 14 yards long, and 8 broad, and which led to another room of the same length, but almost square. Round the inside of both these rooms, close to the wall, and about half a yard high, ran along a kind of bench, covered with a marble pavement, which at first seemed to have been used for a seat, but on coming nearer to more closely examine it, I perceived some of the pieces of marble were round, like stopples; and on their removal, I found they were the covers of some very large *earthen jars*, fixed in with mortar, with their necks inclosed just level with the seeming bench. These vessels were of a round form, and would each contain ten barrels, Tuscan measure. On one of these vessels is this inscription—OPUS, DOLIARE, VINARIUM. The names on the handles and necks of these vessels are those of the makers. The names written with ink were those of the owners of the liquor contained therein. The multiplicity of names caused the conjecture that these apartments had been for the soldiers who were stationed to guard the walls, and that whatever name was written on the vessel, to that person belonged the wine contained therein, whether by purchase or by allowance."

The preceding details having reference to dates indisputably prior to any accredited record with which Europeans are acquainted of the Manufacture by Chinese artisans, do not insinuate priority of operations, yet clearly elucidate what must at any given era have been contemporaneous with them. There necessarily is some obscurity attached to the whole; and, with all inquisitive minds, this I regret, for the industry of research is checked, and the ardour of ambition damped by the fact that the most useful and necessary inventions have not perpetuated any trace

soaked in varnish and then baked. And it is evident that these seggars could not have fixed that portion of heat which would vitrify a glaze, however fusible, as the heat communicated would be only little more than that afforded by the sand-bath in chemical processes.

other than themselves of their inventors, as the most superb and durable, like the less elegant and perishable monuments, have failed to commemorate their subjects and founders.

The earliest written historical records of the Art among the Chinese—the annals of the occurrences, transactions, and subjects worthy of being most particularly remembered, of the city Fou-leang, in the province of Kian-gsi, the district in which is situated King-te-ching, the *localé* of the China Manufacture—mention the productions, as being so excellent, A.D. 442, as to be an object of interest to the imperial court. Such was then its high state of proficiency and perfection, that to these potteries were deputed two mandarins to superintend the workmen while employed in the Manufacture of porcelain for the use of the emperor's household—a most unpleasant affair for the Manufacturers, and the probable cause why no attempts have succeeded to transfer the Art to the capital, Pekin; but, by all who have had opportunity for observation, admitted to be a part of the policy of the government thus obtrusively to interfere with the private affairs of its subjects.

These records, however, are completely silent alike concerning the era of the invention, the name of the inventor, the date of its attaining its acme of perfection, and the master-minds who so successfully improved the processes and manipulations, as to enable the artisans to surpass in excellence of productions those of all other contemporary nations with whom they were acquainted. That the whole series of operations continue unaltered, will not be any cause of surprise to persons who have been informed of the conceitedness of the Chinese in general; and who for a moment reflect, that whenever any attempt is made to introduce improvements into any of the Arts of Life, those who have been employed therein present the chief difficulty, because of the fondness entertained for old practices, in which they, perhaps, are expert, and from regarding each improvement as an idle and useless

innovation on the long-established procedure of their ancestors.

Earthen vessels of truly excellent quality, however, as well as the finest specimens of porcelain,* are yet preserved, that are known to have been made at other cities of the empire, besides those at King-te-ching, and as well as in Japan, long prior to the Christian era. As the wants of mankind increased, in like manner would their endeavours to invent means for their supply. There is no clue to the precise date of the introduction of *Tea Ware* among the domestic utensils of this people, though there cannot be any doubt that their Manufacture would quickly become general, on their convenience and utility being fully experienced. I cannot believe yet, that this was the period of the origin of this Art among this people. It certainly must have been earlier, because it could not immediately rise to that state of excellence in quality and perfection in manipulation adapted to render it of importance at court. Though I am ready to confess, we need not wonder that this people did so soon arrive at the admitted superiority of their productions, and the perfection of their porcelain, when we consider that they have the indispensable earths for their purposes and all other materials, clays or minerals, of recent date discovered as useful by the researches of Europeans.

The fact that close examination of known early specimens, and of others very recently manufactured, in every point of comparison present to the inspection similar characteristic qualities and properties, by indicating that

*Dr. Johnson gives us the etymon of porcelain, *pour cent années*, probably because of the statements that the period of one or two centuries is required to weather the clay for the Chinese potters. Others derive it from the Latin name of the Venus shell, *concha porcelluna*, of the genius Cypræa, partly because the polished exterior of the ware approaches to the beautiful rich surface of the shell, whose peculiar hinge suggests the name, and because only by females was tea-ware first used in Europe. Because of the obscenity of the Latin term, the country supplies the name CHINA.

no alterations whatever have been made in either the materials or processes, may be supposed to militate against the opinion, that, during a long period the Manufacture in this quarter was progressively improving to its admitted station on the scale of excellence, and more especially as there are many known ancient specimens, greatly superior to those usually vended at modern sales; whence comes the observation, said to be of Chinese origin, that the former Manufacture excelled that of the present day. But, in support of the opinion, there is brought another fact, that although the Chinese potters might (and there is every degree of probability that they did) by accident discover and employ the debris of the two families of felspar rocks, *kaolin* and *petuntse*, in forming their ware, yet certainly they did not in like manner discover the appropriation of those substances as at present practised. Many attempts, accompanied with varied success, and requiring a long period of time, assuredly would have been made before the discovery of the proportions requisite to make porcelain, and a much longer time to invent the processes by which the rocks are reduced to a workable state. Every observer must have noticed that the very nature of practice in any of the Arts of Life is the progress to perfection in processes, and to excellence in properties. The Chinese assertion of the superiority of the ancient Manufactures will be allowed by only those who are not aware that the like materials and processes are still employed, and that the natives do not hesitate to employ the most monstrous falsehoods to deceive those strangers with whom they have dealings. That most choice specimens have been obtained from places where they had been buried or hidden several centuries, is readily acknowledged; but those persons who recollect the frequent intestine commotions which have disturbed the Celestial Empire, will regard these specimens as with greater probability hidden, because of their value, by their owners in some civil war and forgotten. The best specimens now manufactured contradict the assertion; and

it is a mere chimera to suppose that a long deposition in the ground is indispensable to render the most valuable articles perfectly beautiful and excellent.

The principal seat of the Manufacture in Britain, the borough of Stoke-upon-Trent, has about 30,000 operatives employed to furnish the requisite supplies of porcelain, flint, and Delft wares for home consumption and exportation to most celebrated places on the globe. We therefore are surprised at the mention that King-te-ching contains 500 ovens, and has 800,000 operatives to keep them constantly supplied. The number seems immensely large, even though it be admitted that here is supplied the porcelain, most esteemed and excellent, purchased by the Japanese merchants for the European markets, in preference to the porcelains of Fo-kien and Canton, which have depreciated value; and, that the imperial court has ever manifested for this ware a decided partiality and preference, and requires the most excellent specimens to be constantly devoted to its purposes. There is certainly one cause, which possibly may render requisite such an immense number of work-people (the writer of the article "Porcelain," in Rees' *Cyclopædia*, assigns it as that for the enormous charge of the Oriental porcelain): "It rarely happens that an oven succeeds throughout; but it is frequently quite spoiled, so that upon opening it, in lieu of fine porcelain is found a hard unformed mass, into which both the porcelains and their coffins [the vessels and the seggars] are converted, either by excess of heat, or some ill qualities in the matter." Yet this writer (like many others who seem wishful to regard all of foreign production as super-excellent), when comparing this Oriental porcelain with that of St. Cloud, which is *infusible*, in entire forgetfulness of the above remarks, says: "the China-ware being made of a paste, part of which is made of a substance in itself scarcely possible to be vitrified, bears the fire in yet much more intense degree than ours, and is in no danger of running wholly into glass from it." Parkes makes an

equivalent assertion, and no doubt both imagine they are correct. Let them just reflect on the components of the *paste* and the *glaze*, and they will readily understand the *tremendous* heats of the Chinese ovens.

Satisfactory information has not been obtained of the precise date of this proud conquest of our ancestors—the establishment of the Manufacture in the district, now the borough of Stoke-upon-Trent, but that it preceded the introduction of the Saxon tongue etymology clearly demonstrates; BURSLEM has its name from being the *locale* of the Manufacture; and the different enunciation of the compounded names of *the same primary ideas* has caused the scribes of the times to vary the orthography, as *Bwlwardeslœm*, *Bwlwardslene*, *Bwryeardeslyme*, *Burewardeslime*, *Barcardeslim*, etc. The force of each part of the compound will appear clearly thus: *Burn*, *byrn*, a small rill of *water*, its receptacle being a *bwl*, *bwr*, *bwc* (bowl, burl, bowk); *wardes*, *yeard*, *cardes*, a spot *wared*, guarded, *looked over*, (yard, a farm-yard tan-yard, church-yard and garden, quarry, are cognate terms); *lœm*, clay, earth, *lœmen*, earthy, *lemm-faet*, the *feat* in loam, work in clay; and lyme, lene, lime, are kindred forms. The words then originally signified—*a vessel to contain water*, *a guarded spot of land*, and *the earth* of which the vessel was fabricated, and hence the true import of *Burslem* is—*the* SPOT *where is* QUARRIED *and used* CLAY *for* POTS. The small utensil for conveying drink to the mouth, because of its purpose was named *tyg*, or the *touched* pot, corrupted into *tot;* and the maker of drink-cups was named *tygel wyrthan*, workers of tygs (still retained in Saxony). On other etymologies it were invidious to offer any remarks.

Reasoning on the importance to a nation of the successful fabrication of valueless earths into vessels of considerable value, it would be supposed that there would be made great endeavours to discover the materials and completely develop the processes by which to conduct at home the Manufacture of porcelain, similar to that which from Japan

and China found its way into the western states of Europe; and, being the ornament of sumptuous tables, and the admiration of persons of opulence and taste, was increasing in demand. And yet the broad tablets of history show the negative of such surmises. Such had been the prevalence of ignorance and barbarism; the inability of the poor, and the indifference of the rich; the indolence of the ingenious, and the apathy of the active; the vigorous pursuit among the European states of the Arts of destructive warfare, and the negligence of those of social comfort and peace, as present the lamentable facts, that, during sixteen centuries of the Christian era, in which regard to the injunctions and precepts of the Divine Founder should and would have promoted public prosperity, and increased the sum of human happiness, all attempts whatever for the above important and useful purposes were either altogether disregarded, or remained completely unsuccessful, even though incessantly aided by the almost incredible efforts of the Jesuit missionaries in the east.*

* The indifference of nations, however, to their best interests, did not prevent the appearance of individuals, who, disregarding every obstacle, aimed at accomplishing some important addition to the stock of public wealth. The following worthies are connected with earthenwares:—

Luca della Robia, of Florence, born in 1388, afterwards a goldsmith and statuary, manufactured of *terra cotta invetriata*, or glazed earthenware, of good quality, and agreeably to the fancy of the purchaser, at pleasure white, brown, blue, green, or yellow, vessels of the kinds needful for domestic purposes; and in relief, busts and figures of saints, in truly excellent style of sculpture, and in our day numerous in the churches of his native city. The workmanship does great credit to the talents of the artist; and the composition of the materials, though certainly the result of accident and observation without the helps of theory, seems as perfect and equivalent as if there had been employed the fullest attention to the laws of chemical combination.

Castel Franco, in 1510, manufactured, at *Faenza*, excellent *Majolica*, the Italian name for *Earthenware* named *Fayance* by the French. Many of his productions were ornamented by the pencil of Raphael (according to the information given me by the late Jacob Warburton), and the specimens yet preserved in many collections cannot fail to excite surprise that so few improvements have been made, and such a long intervening series of years has

While engaged in the fruitless attempt to introduce the tenets of the church of Rome among the inhabitants of the extensive empire of China, into whose estimation they

elapsed to bring the Manufacture to its present state in the several European nations.

Bernard de Palissy, neglected during his career, but now named only with exultation, born at the close of the fifteenth century at Agen, in France, versed in the chemical knowledge of that age, and with his acquirements uniting both superior talents and industry in the Manufacture of fayance, and especially its glaze, made great improvements by the most astonishing perseverance. Of humble origin, and employed as a draughtsman and land-surveyor, accident presented him with a cup of Italian *fayance*, whose glaze and beautiful enamel-painting caused the powers of his mind to be devoted to produce ware equally excellent; and only to his own indefatigable energy and unquenchable thirst for full accomplishment does he owe the success which ultimately brought this Manufacture into celebrity in France, and secured to himself fame, honours and independence. The narrative of his labours, sacrifices, and privations is a most instructive piece for a person commencing the study of useful sciences; and most sympathetically do I respond to many of the bitter remarks he so pertinently makes. As a self-taught painter his industry and efforts were inadequate to provide for his family; and during the anxiety consequent on the failures, to which "hope told a flattering tale," the idea of advantages from knowledge of the fabrication of such ware took full possession of his thoughts. Imagining that whatever trouble or difficulty might attach to the acquisition, the termination of his miseries would ensue from his success, he determined to assiduously employ every moment he could spare, every effort he could make, and all the means he could obtain, however limited in quantity and amount. One of his productions supplied funds to commence his processes, but their results proving entire failures, he was thus more reduced, and had the additional annoyance of the remonstrances of relatives, who deemed his design chimerical, and the earnest entreaties of his wife that he would relinquish his ruinous project. Persuaded, however, in his own mind that success was within his reach, at exorbitant interest he borrowed money from parties willing to lend, and which he expended without any other than mere trifling success. Now he was necessitated to give part of his clothes to induce his assistant to continue his aid; and failing of funds to purchase fuel, his chairs and tables were substituted and consumed. His wife and family justly complained of the privations they endured, and his own feelings were constantly agitated by witnessing these, and failure of his researches, during about sixteen years; yet his common cheerfulness prevented his friends becoming acquainted with his really destitute condition. And at length complete success crowned his efforts; the productions of his ingenuity became of national importance, and secured to himself and family opulence and distinction.

might successfully ingratiate themselves, the missionaries of the Society of Jesus had to adopt every method, and resort to every practice, short of sin and infidelity; but persons acquainted with the history of that society know, that an object regarded as requisite was never relinquished in consequence of obstacles being presented. The Manufacture of porcelain, as practised in China, was a *desideratum* to France, and the veil thrown over all the processes had been impenetrable by every effort of the Dutch and English merchants. The development, however, was undertaken by one of the above-mentioned society, who is entitled to grateful remembrance as a benefactor to Europe at large. With only a very limited knowledge of the construction of machinery, and a restricted acquaintance with the properties of mineral productions—even had the Oriental processes been in any way adapted to suggest rather than to retard improvements in those of Europeans—his descriptions are defective in precision, yet only perhaps because of misinformation. The indefatigable friend of his country, the Father FRANCIS XAVIER DE ENTRECOLLES, during a long residence at King-te-ching and its vicinity, by the suavity of a mild deportment and amiable manners eluded the jealous vigilance usually exercised towards strangers, and by much intrigue, unparalleled assiduity, and a very bland and insinuating address, secured the friendship of some of the less suspecting of the potters, was favoured with opportunities to witness the processes and manipulations of the Manufacture, and obtained ample specimens of the two chief materials, the *kaolin* and *petuntse*. He fully detailed all the particulars in a letter, dated *Jauchew* (or *Jaotcheou*), *Sept.* 1, 1712, which he transmitted, with the specimens, to the Jesuit Father Orry, of Paris, by whom the information was quickly spread; and to more generally diffuse it, Crosier published the details in his *General Description of China*.

The return from the east of the few warm-hearted enthusiasts who had engaged in the Crusades, made those

nations to which they belonged better acquainted with science. They had also imbibed the error of transmutation, and caused all the known metals to be tortured in every way likely to supply the precious metal sought. In the different cities of Europe the practices of some alchemists —those labourers in the ardent laboratory of metallurgy —had introduced the Manufacture of Common Stone Ware, having proved that it only could with security be employed in the intense heats to which their furnaces were occasionally raised, and which a judge of no ordinary ability, Macquer, asserts, "is the most perfect pottery that can be, possessing all the essential qualities of the finest Japanese Porcelain." To render these vessels more easy to be cleansed, and retentive of any chemical compounds or preparations, without being permeated thereby, vitrification of the surface was affected by fusing the silica in combination with soda during the decomposition of common table-salt. In this, as in many other of the processes, with little real chemical knowledge of the properties of substances, nor any exemplars of what they wished to produce, the simultaneous endeavours of several persons to introduce something new obtained some partial success; a close investigation of one subject frequently reflected additional light on some other; results, altogether unexpected, were presented to notice, and often an incident, comparatively trivial, occasioned a discovery of paramount importance

Prior to 1700 a professed alchemist from Switzerland had frequently visited the shop of a druggist in Magdeburg for the various articles required in his researches for the *Elixir Vitæ*, the Philosopher's Stone, and the Powder of Projection. Like most of his compeers in the delusive task, blinded by the avarice which stimulated perseverance in the unproductive labours, he seems to have altogether overlooked, or entirely disregarded the numerous intimations given by the processes that the attention was courted to transpiring facts, from which valuable and truly important discoveries have since rewarded the patient observations and

assiduity of minds better regulated to the consecutiveness of scientific investigations. The druggist had an apprentice, named John De Bötscher (mentioned already at page 5), whose kind attentions and repeated manifestations of readiness to oblige the alchemist, even at some personal inconvenience, so won the regard of the enthusiast as to induce him to communicate in detail correct information relative to the customary processes and manipulations in chemistry, which were regarded as indispensable to the full effecting of transmutation. About 1700 the alchemist fell a victim to his unhealthy experiments, like many another engaged in chemical researches, and the young man became possessed of his papers, and retained them for his own purposes, at an age the most critical for the proper formation of character. Dishonourably disregarding the connection between his master and himself, and indifferent to the possibility that himself might become a houseless wanderer, elated with his possession of the treasury in which were deposited the important secrets, at that time the objects of such assiduous labour to the initiated, and buoyed up with the supposition that both health and opulence were now within his command, he absconded to Berlin, and announced his acquisitions and purposes for the benefit of the citizens. Leibnitz says: "Without my being able to explain how it came to pass, I know he took to gold-making, and revived the almost expiring hopes of the alchemists by extraordinary proofs of his skill. Several eye-witnesses aver, that in their presence, as he was about to leave his master, he threw thirteen pieces of copper money, which one of those present gave him, into a melting-dish, and after they were melted, he added to them a piece of some substance that resembled dark-coloured glass, and almost immediately afterwards poured out of the melting-pot a piece of fine gold, equal in weight to the money employed. This took place before he received instruction from the celebrated Tschernhausen, in Dresden." On his master discovering the place of his apprentice's retreat, justly considering himself entitled to the advantages

resulting from his industry, and hoping to derive opulence from the alchemist's papers, he pursued the fugitive, had him apprehended, and before the judicial authorities of Dresden stated his claims, and urged the committal of the young alchemist again to his care and protection. His journey, however, ended in complete disappointment. The reigning prince had some peculiar views of the whole affair; whether he indulged the hope of ultimately obtaining from the youth's possession of the secret or not, he hesitated to decide the case, and seems not to have been disposed entirely to neglect so favourable and remarkable an opportunity for readily enriching himself as was thereby unexpectedly presented. Under the pretext of more fully considering the merits of the case, he detained De Bötscher in the castle of Koningstein, but gave to the keepers secret instructions to supply him with all kinds of materials he might need in whatever experiments he might feel disposed to make, either for employment of his time against *ennui*, or in pursuit of his chimerical researches. In this condition, at only the expense of his own labour, and the cost of the prince, he had ample opportunity and sufficient leisure to make memorandums of the compounds, proportional quantities, and results, in his multiplicity of experiments and mortifying failures. Yet he had not opportunity to either mal-appropriate or destroy the least portion of the products. Some specimens of metals obtained during the course of his researches, instead of inducing the prince to liberate the *detenu*, prompted the more his avaricious expectation of ultimate successful results. De Bötscher's crucibles failed under the extremely high heat of his furnace, which he deemed requisite to fuse some of the minerals. The fabrication of others more refractory engaged his attention, and without determined knowledge of the qualities of minerals and stony masses, he mixed and remixed at random for some time. However, the period of his liberation came more quickly than he might have expected, however highly desirable he might consider it. On one occasion, ignorant

of the natural qualities of the substances, and of their chemical tendencies when affected by high temperature, he mixed some minerals whose natural properties are exactly similar to those of the kaolin and petuntse employed by the Chinese in the Manufacture of porcelain, and most unexpectedly he found his crucibles, formed of this compound, refractory in the most intense heat he could command. And to his great surprise and gratification, he found likewise what his most ardent fancy had never once imagined, the crucibles, when cold, were of a pale flesh-colour, semi-vitreous, semi-transparent, and so compact and firm as to receive from the lapidary's wheel a polish and lustre equal to that of the best glazed porcelain. The repetition of his processes satisfied him of the importance of the discovery, thus accidentally made, to the commercial resources and revenues of the country; and while prudence urged to the concealment of the substances and proportional quantities, he had sufficient wisdom to immediately discontinue all pursuits of the objects for which he had been primarily incarcerated, and devote all his mental energies to the perfecting of the discovery which now presented itself, as likely to be incalculably more valuable to himself, and much more useful to society, by promoting individual industry, and so inducing comfort and prosperity. The apartments of the Japan palace at Dresden now contain numerous specimens of the kinds of ware he made, while he was busily engaged in perfecting the composition of the *white real porcelain*, in imitation of the imported productions of China and Japan. The prince himself had both the honesty and honour to avow the debt due to the youth who had thus introduced a subject of inestimable value to his dominions, not indeed for success in alchemy, transmuting the metals into gold, but for transmuting the rocks into elegant vessels adapted for both usefulness and ornament; for transforming the *mire* and the *clay* into a valuable article of commerce; and to award, as a compensation, a patent of nobility with ample possessions to support the dignity. The white porcelain,

the Manufacture whose establishment was the ultimate result of the discovery, was the only kind made during the life of De Bötscher, and merely a little improved was continued for the private advantage of the king of Saxony; but about three years after his death, the Manufacture of coloured porcelain was successfully introduced, and the excellence of the productions has secured them a value rivalling the most choice specimens from the celestial empire. The other European nations were no otherwise benefited by this discovery, than as regarded the stimulus given to the exertion of genius and research. For with a jealousy too common, yet not the less to be regretted, to preserve veiled in impenetrable secrecy every process for the Manufacture of the Dresden porcelain, the place selected as the arcanum for their seclusion was the ancient castle of the Albrechtsberg, situate on a rock more than eighty feet above the bed of the river Elbe, at Meissen, near Dresden; and here, in cells, all the persons employed in the processes were as completely immured, as if crime had been the cause of their incarceration.

The announcement of De Bötscher's, perhaps we ought to say, invention, and the remarkable success which attended the Manufacture of the Dresden porcelain, communicated such impetus to the operations, and so stimulated the researches of the potters of Britain and France, that a great variety of productions resulted, each differing from the others, and presenting a beautiful appearance on the exterior; but all, more or less, obviously deficient in the qualities essential to real porcelain, and much surpassed in excellence by the productions of Dresden, as well as those of China and Japan; and because of their open grain and texture, as also of their ready fusibility at a moderate degree of heat, distinguished among connoisseurs by the general appellation of *Soft* or *False Porcelains.*

The arrival of the specimens sent from China by D'Entrecolles, was regarded as of such importance to the manufacturing interests of France especially, and was the

cause of such expressions of satisfaction, that without the least delay to ascertain their components, relative proportions, and chemical qualities, or whether the researches of the mineralogists would be successful in discovering that France (as was proved in 1739) possessed in the quarries of Alençon and St. Yrieux, near Limoges, the same family of minerals which supply the kaolin and petuntse, and which would render less difficult the perfect imitation of the admired oriental productions, Réaumur, the amiable, intelligent, philosophic, and celebrated friend of the Arts, devoting the greater portion of a long life to benefit his country, with true patriotism, at St. Cloud immediately commenced a series of experiments, which he indefatigably pursued, to develop the essential properties of porcelain, ascertain the agreement or difference of those of Dresden and China, and elucidate the most felicitous methods for establishing a rival Manufacture. He found Japan porcelain, in grain and texture, close and compact; in appearance, shining, smooth, and infusible in any heat he applied; De Bötscher's porcelain, not granular in texture, but more compact than that of Japan, smooth, and vitreous like enamel. After much labour and frequent disappointments, his reasonings were fully demonstrated by the characteristic properties of the Japan porcelain: when a substance which is, *per se*, fusible at a known temperature (as he found the petuntse), is mixed with a determined proportion of another substance, *per se*, infusible at any temperature (as the kaolin proved), the fusible component flowing by the heat, which even much increased does not alter the infusible, there will be formed a vitrified compound substance, such as is the Japan porcelain. To verify these reasonings, he mixed different proportions of the Chinese minerals in their crude, and also in their prepared states, subjected them to proper baking, and had the great satisfaction to find certain of them, in grain and texture, much similar to the Japan ware. The results suggested the improved French porcelain, in grain less close and fine than that last mentioned, with a fracture

like fine sugar; and, formed of the earths, whose announcement is thus made in the *Transactions of the Academy of Sciences, Paris* (1739): "We have in Europe substances of the very same nature as the oriental petuntse and kaolin, and capable of being worked into a porcelain equally beautiful and fine." The experiments had been published in those *Transactions* in 1729, ten years after the death of De Bötscher. Ultimately they caused the establishment of the deservedly celebrated Sevres Manufactory, under royal patronage, where are produced specimens of Art which will bear the most scrupulous comparison with the choicest obtained from Dresden and China, the directors being devoid of fear of expense, and by restrictions on private Manufactories, secured from the effects of competition, while availing themselves of every important suggestion by persons of scientific acquirements adapted to promote improvement. Réaumur, in 1739, also published the process by which he so devitrified glass as to form the peculiar substance which is named, not for its properties, but its appearance, *Réaumur's Porcelain*, very useful and durable for fabricating vessels in many of the processes of the laboratory. His early attempts were on mixtures of saline fluxes with vitrescent minerals; and he imbedded in plaster of Paris, or sand, green bottle-glass, subjected it some time to a heat below the fusing point, and found the specimens semi-transparent, scintillative with steel, and uninjured by sudden transitions from high heat to cold, as well as in many properties resembling Japan porcelain.

Scarcely need I mention, that on the principles already stated a great variety of different wares may be readily fabricated of earths not possessing equal fusibility. The facts are evident in the number of Manufactories: St. Cloud, Fauxbourg St. Antoine, Paris, Chantilly, Villeroi and Orleans; Naples, Florence, Vienna, Frankendal, and Berlin. Yet the connoisseur easily distinguishes the Oriental from these, which derive their beauty from near approach to vitrification, and being allowed to cool at the

time when a little longer duration of the high heat would have completely fused them into glass or slag; the other (and partially so those of Berlin and Vienna, which are of the same materials as that of Dresden), having one component scarcely possible to be vitrified, endures the intense heat which completely vitrifies the other component, without becoming glass.

The following facts will suggest an idea of the anxiety felt in Britain on this interesting subject: One of the members of the Royal Society of London, Dr. William Sherrard, visited Paris about the time of the publication of De Entrecolles's letter, and he quickly communicated the contents thereof to that celebrated assembly, and enriched their museum with specimens of the native minerals, and of the prepared petuntse and kaolin. How many of the chemists and mineralogists of Britain have availed themselves of the opportunity for careful examination, to assist them in their researches whether and where any minerals with similar properties were to be found in Britain, we have no means whatever to ascertain. And: That notorious literary impostor, the French jesuit, George Psalmanazar, attempted to pass for a native of the island of Formosa, and with such temporary success, that he obtained a very considerable sum as a gratuity from a potter in the vicinity of London, for permission to use his name in a design then contemplated, an attempt at the Manufacture of porcelain; which failed, and deservedly, because deficient in all the essential properties of real porcelain, but was pompously announced, and for a short time obtained considerable celebrity, as "*A curious white Formosan work*, made agreeably to directions obtained from a native of that island." Not these attempts, but all others made by our countrymen in England, until 1820, were unsuccessful in producing real porcelain, owing to the chemical properties of the minerals used by the Chinese being very imperfectly detailed; and their existence in immense quantity, and truly excellent quality, having remained till that time undiscovered. But

such as was the numerous varieties of soft porcelain, for merit in the workmanship I shall be excused for denying any inferiority whatever. I shall insist on prior claims of our artisans for improvements in the processes and dexterity in the various manipulations, decidedly superior to all others; and for our artists, that skill and taste in ornament which at the lowest estimate is equal. The productions of the celestial empire, in scarcely any particular instance, will bear comparison—neither will those of Dresden, Sevres, and Berlin be disparaged by it, for chasteness of model, grace, and symmetry of figure, and elegance of execution—with the productions of Derby, Worcester, Coalport, or the (*new*) Borough of Stoke-upon-Trent; and the really uncouth figures and unmeaning scenes, delineated to embellish the oriental porcelain, the connoisseur will not place in competition, for delicacy of colouring and accuracy of tracing, with the natural landscape, the assorted and tasteful bouquet, and the grouped animals pleasingly depicted, so elegantly painted on British porcelain and flint wares.

The celebrity and success of the two royal Manufactories of Dresden and Sevres excited the cupidity of Frederic II. of Prussia; who, from political motives, and a conviction of the importance of the Manufacture, about 1762 first established the Royal Manufactory of Porcelain at Berlin, for the private advantage of himself and his successors. To ensure its success, and extend its operations, he embraced every opportunity that was presented. His conquest of Saxony was subservient to the expatriation of many of the most clever and expert workmen in the Manufactory at Meissen, near Dresden, that their productions for excellence, elegance, and beauty, might rival in celebrity those of Dresden and Sevres. He presented to each German Prince and Sovereign complete services for the toilet, breakfast, dejeune, dinner, and dessert, the more extensively to diffuse the knowledge of their place of fabrication. And the better to ensure employment for the 500 persons engaged in the processes, he restricted the

Jews resident in any part of his dominions from entering into the marriage state until each man had obtained a certificate from himself, which was only granted on the production of a voucher from the director of his Manufactory, that porcelain to a given amount had been then purchased, and that there was a reasonable cause for claiming such indulgence. Of course, the Jews more readily disposed of their purchases than the general dealers, and the device was attended with much success. This porcelain remains inferior to those it was intended to rival, though it is proper to mention that in Berlin are other Manufactories; and at those of MM. Fielner and Gormann has been introduced very successfully the fabrication of earthenware ornaments for churches, many of which adorn the sacred edifice of St. Stephano.*

Of the progress of the Manufacture in Holland I am not in possession of any information. But that it was not stationary, and that among the Dutch potters were some master-minds, will, I think, clearly appear from the statement now to be made. From Nuremberg, in Holland, two brothers, named Elers (a name connected with the chemical researches of that period), followed their countryman, William III., in 1688. And quickly must they have located themselves in the immediate vicinity of the Manufacture in the county of Stafford, for prior to 1690 they

* The process is the following: Into the plaster moulds the soft clay is at different times introduced in small quantities, and into the various cavities carefully pressed with the fingers. After the requisite quantity of clay has been thus gradually forced into the mould, by strong mechanical pressure applied to the entire mass, the clay is condensed, yet forced into the most delicate lineaments and indentations; and to ensure yet greater cohesion, which is indispensable that it may sustain the high heats of the furnace in baking equally and uniformly, in the centre of the thicker parts of each figure are carefully placed round pieces of white wood. These very durable and elegant ornaments, thus readily formed, exhibit a firmness of substance, accuracy of outline, and delicacy of execution, which even the best sculptors can scarcely equal, not to say excel, in their operose labours on the finest marble.

were busily engaged in their particular branch, in the secluded spots of Dimsdale and Bradwell, both within two miles of Burslem, but from which the former, not at all, and the latter scarcely is discernable; and equally without annoyance from the potters of Red Street. No inquiries now avail to show how the Manufacturers, born on the spot, in a manner, had neglected to husband well their own resources; and, independent of the supply of coal, how these strangers happened to be the first discoverers of the peculiar kind of clay in this neighbourhood (and veins of which are still kept open for supplying the same, fine in grain and dark in colour, for the *mocha dip*, in the field west of Brownhill's toll-gate, and in the path through Bradwell Wood near Chatterley), which would be so successfully used in the Manufacture of ware that would imitate the oriental dry body or unglazed red porcelain. But in 1690, from the native clays of Bradwell and Chesterton, carefully levigated and passed through fine hair-sieves, and then artificially evaporated, they were manufacturing, to considerable extent, an improved kind of red porcelain, and with manganese added to the clays, of *black*, a knowledge of whose components was the origin of Wedgwood's Egyptian. The specimens yet preserved, by their excellence in grain, texture, and shape, although the ornaments are truly grotesque, will ever manifest the skill and success of the foreigners. Their extreme precaution to keep secret their processes, and jealousy lest they might happen to be witnessed accidentally by any purchaser of their wares—making them at Bradwell, and conveying them over the fields to Dimsdale, to be there sold, being only two fields distant from the turnpike-road; and having some mode of communication (believed to be earthenware pipes like those for water laid in the ground), between the two contiguous farm-houses to intimate the approach of persons supposed to be intruders—caused them to experience considerable and constant annoyance. In vain did they adopt measures for self-protection in regard to

their manipulations, by employing an idiot to turn the thrower's wheel, and the most ignorant and stupid work-folks to perform the laborious operations; by locking up these persons while at work, and strictly examining each prior to quitting the Manufactory at night; all their most important processes were developed and publicly stated for general benefit (as already detailed, p. 249). Mortified at the failure of all their precautions, disgusted with the prying inquisitiveness of their Burslem neighbours, and fully aware that they were too far distant from the principal market for their productions, even had not other kinds of porcelain been announced, which probably would diminish their sales, about 1710 they discontinued their Staffordshire Manufactory, and removed to Lambeth or Chelsea (where is, at this day, a branch of the family), and connected the interests of their *new* Manufacture with those of the glass Manufacture, established in 1676 by Venetians, under the auspices of the Duke of Buckingham. Others, however, have stated that their removal was consequent on misunderstanding and persecution, because their oven cast forth such tremendous volumes of smoke and flame during the time of glazing, as were terrific to the inhabitants, of Burslem, and caused all its (astonishing number of *eight*) master potters to hurry in dismay to Bradwell.* I think my readers will smile at the affair, when informed, that at this date, or 1707, the numbers were so great as to have twenty-four paupers in the whole parish—nine aged men, eleven widows, and four orphans—to whom was paid monthly the large sum of three pounds four shillings and one halfpenny! towards which one pound ten shillings

* Had this relation been connected with the then close and exclusive policy of the neighbouring borough of Newcastle, I should the less have been surprised; for, half a century afterwards, the corporation acted an equally unwise part, in proscribing the Manufacture in the limits of its authority. Too often does research develop instances in which the existence of many of the Arts of Life has depended on police regulations; and manufacturing industry, also the

and nine pence was provided by Cartwright's legacy (page 414).

Several writers having ascribed to the brothers Elers the introduction of *salt glaze*, I shall not be censured for giving the results of my inquiries relative to the same. Without taking into the account, what some would regard as conclusive, that the knowledge of glazing earthenware by means of salt, and its kindred substance, soda, was current in Britain, not merely amongst potters—as proved by these remarks, extracted from Dr. Plott's *Circular* on his projected Itinerary for collecting Materials for his Works on the English Counties, in which, with other valuable suggestions he states, that he should particularise "all such herbs as are of use in trade: as wold for dyeing, kali for glass-works, fucus maritimus or quercus maritima, which grows plentifully in the Isle of Thanet; they burn it to ashes, and then it is called *kelp*, which is put into barrels and carried over to Holland, *with which they glaze all their earthenware*," and which may well be regarded as known to the potters of Burslem and its vicinity—there are proofs, by specimens at this day well stored, that about 1680, Palmer, at Bagnall and in Burslem parish, Adams. in Holden Lane, and Wedgwoods, of Green Head and of Brownhills, glazed their ware with common salt and a small quantity of litharge. This was ten years anterior to the brothers settling at Bradwell. The practice is, by tradition, ascribed to the following occurrence: At Mr. Joseph Yates', Stanley, near Bagnall, five miles east of Burslem, the servant was preparing, in an earthen vessel, a salt ley for curing pork; and during her temporary absence the liquid boiled over, and the sides of the pot were quickly red

manufacturer's welfare, have been rested on the frail basis of the caprice of a magistrate. Driven by ignorance, prejudice, jealousy to a distance from materials, workmen, or market, some manufacturers continue to endeavour to surmount the obstacles which oppose their progress and maintain a disadvantageous struggle with the difficulties of their situation.

hot from the intense heat; yet when cold, were covered with an excellent glaze. The fact was detailed to Mr. Palmer, potter, of Bagnall, who availed himself of the occurrence, and told other potters. At the small Manufactories in Holden Lane, Green Head, and Brownhills, salt-glazed ware was soon afterwards made, and was in practice when the brothers Elers settled at Bradwell. The facts had long been known that, on being cast into a fire (common table-salt) chloride of sodium is decomposed, and by causing a more rapid fixation of oxygen the heat is much increased; also, that when it was mixed with sand and exposed to considerable heat, a vitrescent substance was the result. These facts suggested the trial, which proved successful, that, when the potter's oven had been raised to the proper temperature, which adequately continued would dissipate the water held by the alumine, if salt were introduced, not only would the heat be much raised, but the alkaline vapour diffused through the oven by the flame would combine with the silica on the surface of the vessels, and by semi-fusion form thereon a covering of durable glass, the chemical combination of the proper quantities of silica and alkali leaving the ware with a vitreous appearance. The ovens employed for the purpose, being used only once weekly, and the ware being cheap, were large in diameter, and very high, to contain a sufficient quantity to be baked each time to cover all contingent expenses; they were constructed with a scaffold round them on which the fireman could stand, while casting in the salt through holes made in the upper part of the cylinder above the bags or inner vertical flues; and the saggers were made of completely refractory materials, with holes in their sides, for the vapourised salt to circulate freely among all vessels in the oven, to affect their surfaces; plenty of specimens yet remain. The oven used by the brothers Elers was taken down within the recollection of oven-builders yet alive (1836), who describe it as adapted to bake choice articles (and salt glazed and dry body

wares will not bake together), without holes over the bags, or scaffold around its sides. A long time intervened between Mr. Booth's introduction of fluid glaze and its general adoption in the Manufacture; and I think we may expect that a longer time would have elapsed between the first introduction *secretly* by the brothers and its adoption by the chief Manufacturers, not to say the commencement of a suitable kind of ware on which its effects would be most useful. Researches on the spot have supplied only fragments of red, black, and blue (the last probably made by Mr. Cookworthy, or his relative Mr. Marsh, who occupied the farm afterwards), and I regard the *persecution tale* as a mere *ruse* to cover the sudden removal.

Much misapprehension has existed, on the supposed authority of Dr. Plott for the opinion, that the *Butter-pot* claims priority of date for fabrication; whereas, unless other pots had been made, there does not seem anything to suggest the appropriation of clay to form receptacles for butter. The relation by Plott certainly is not perspicuous; but no one can misunderstand his observations, that—"the several sorts of pots, of as many different sorts of clay, in twenty-four hours burnt, they draw for sale to the crate-men, to whom they reckon them by the piece"—have regard to other kinds of ware, wholly distinct from butter-pots.* Indeed, had Thomas Cartwright, who died in 1659, made only that kind of ware, even had there been only very

* Having frequently heard the ingenious device of the *Well* or *Gravy-dish* ascribed to Wedgwood, and one or two other celebrated Manufacturers, his contemporaries, at the latter part of the eighteenth century, I was surprised on reading what establishes the fact, that to none of these parties, nor to any modern, is the merit due of the useful invention. However much I may delight in rendering to every person the due meed of praise, where there is no claim, I am not required to create one. The ingenuity was that of some party long ago commixed with his native earths; as many specimens, dishes with a similar receptacle, and common in the refectory long prior to the Christian era, have been obtained from Herculaneum and Pompeii, and are at this day preserved in the Studii Museum at Naples.

few competitors, I cannot be of opinion that he would have realised property to warrant his then munificent bequest of *twenty pounds* per annum, to the poor of Burslem for ever.

There remain in different parts of the district tiles bearing the date 1460, and the specimens, which are precisely similar in quality, density, and appearance, are concluded to be contemporaneous. Although of different kinds, they do not present any indications of mixture of materials and change of processes; but subsequent to that date, by other specimens, we readily trace improvements from the introduction of some fresh material.* The trifling knowledge possessed concerning the general nature of mixtures appeared to have been excited to further operation by the accidental baking of a small portion of the fine dark red clay, or the aluminous shale; and they were introduced in varied quantities as they were better known, at the first for the purposes of ornament, and ultimately in the body of the ware.† And when mixing was once commenced, as the

* An excellent series of specimens are in the museum of the Pottery Mechanics' Institution, supplied out of many thousands by the liberality of that venerable lover of the Art, Enoch Wood, Sen., Esq., who, indulging the philosophical idea of collecting whatever remains of the Manufacture were presented to his antiquarian researches, has rendered easy the reference to respective eras, by arranging them, all prior to 1600 together, and all subsequent in half centuries to the present time, 1836.

† The spirit of indifference to the gratification which would be afforded to posterity by persons recording their observations of the small commencements and gradual progress of the Manufacture, has caused some trouble to discover and trace the obscure yet ceaseless steps of the appropriation of clays. Most of the natural silicates being with moderate labour and expense accessible, there was needful only some modification. The early potters mixing the clays by bowk-fuls, as 1 + 1, 1 + 2, 2 + 3, 3 + 5, had the baked product to afford the criterion of the utility of the proportions, in accordance with the required kind of ware; and the least variation in these proportions would vary the quality of the ware, distinguishable by the judicious workman, and thereby raising up a more than usual impediment to the proper dissemination of science.

processes varied, the guesses at proportions might have been with almost the fertility of arithmetical progression. On viewing these specimens, and others subsequently fabricated, and attentively comparing the progress of the Manufacture, I am of opinion that it has been, from employing the different materials plentiful in the vicinity, the common potter's clay, as first quarried in the mine; next, a finer kind, from the bassetings of the coal strata, the aluminous shale; these afterwards much disintegrated by exposure to the alternations of the atmosphere, and, mixed with water by violent agitation, passed through a hair-sieve upon a *sun-pan*, or small tank, on whose level surface the mass is by solar heat evaporated to the consistence proper for working; next, the finer clays, in like manner mixed and dried, used to ornament the other, and in the sequel entirely superseding all others. In this succession I find the *common brown-ware* till 1680; then the Shelton clay (long previously used by the tobacco-pipe makers of Newcastle, *Plott*, p. 121), mixed with grit from Baddeley Hedge, by Thomas Miles, of *coarse white stone*-ware, and the same grit and can-marle or clunch of the coal-seams, by his brother, into *brown stone*-ware; the *crouch-ware* was first made of common potter's clay and grit from Mole Cob, and afterwards, the grit and can-marle, by A. Wedgwood, of Burslem, in 1690; and the ochreous brown clay and Manganese into a coarse *Egyptian black*, in 1700, by Wood, of Hot Lane; the employment of the Devonshire pipe-clay by Twyford and Astbury, of Shelton, supplied the *white dipped* and the *white stone-ware*, from which the transition was easy to the *flint-ware*, by Daniel Bird, of Stoke; the *chalk body-ware*, by Chatterley and Palmer, of Hanley, and the *queen's-ware* of the celebrated Josiah Wedgwood.

Having now brought to our own homes this interesting Manufacture—this honourable, important, and lucrative branch of domestic industry and foreign commerce—it only

remains for me to enable the reader with myself to take familiarly by the hand, and make grateful acknowledgments to its early sons, residents of this district; those worthies of former days, in the infancy of the art noted for fabricating earthenware, coarse in quality, because *mixing* of clay was scarcely if at all known and practised, and rude in workmanship, because adapted only for common uses, yet commencing and establishing the art on a permanent basis; also those master-minds of each era, whose genius, talents, and indefatigable perseverance—to introduce fresh materials to supply wherein was deficiency, and to remedy what current knowledge showed to be erroneous; to invent fresh implements, utensils, and ornaments, superseding the inconvenience experienced—have completed the superstructure in a state of excellence worthy its consequence, and of perfection probably much surpassing their predecessor's conceptions of its susceptibility: Mr. Thomas Toft, for introducing aluminous shale, or *fire-brick clay;* Mr. William Sans, *manganese* and *galena* pulverised; Messrs. John Palmer and William Adams, *common salt* and *litharge;* Messrs. Elers, Brothers, *red clay,* or *marle* and *ochre;* Mr. Josiah Twyford, *pipe-clay;* Mr. Thomas Astbury, *flint;* Mr. Ralph Shaw, *basaltes;* Mr. Aaron Wedgwood, *red lead;* Mr. William Littler, *calcined bone-earth;* Mr. Enoch Booth, *white lead;* Mrs. Warburton, *soda;* Mr. Ralph Daniel, *calcined gypsum;* Josiah Wedgwood, Esq., *barytes;* Mr. John Cookworthy, *decomposed white granite;* Mr. James Ryan, *British kaolin* and *petuntse;* Messrs. Sadler and Green, *glaze-printing;* Mr. Warner Edwards, *biscuit-painting;* Mr. Thomas Daniel, *glaze enamelling;* Mr. William Smith, *burnished gilding;* Mr. Peter Warburton, *printing in gold;* Messrs. John Hancock, John Gardner, and William Hennys, *lustres;* Mr. William Brookes, *engraved landscapes and printing in colours;* Mr. William Wainwright Potts, *printing by machine,* and continuous sheet of paper; and the same gentleman, with Mr. William

Machin and Mr. William Bourne, for *printing flowers, figures, etc., in colours, by machine*, and continuous sheet of paper.*

* This improvement admits of a delicacy and precision, a clearness and fineness in the work of the pattern, unattainable by the usual mode of printing by hand—alike difficult, operose and unhealthy. All this is effected by substituting a *cylinder* for a *flat plate* of copper; worked by apparatus, simple in principle, which simultaneously applies the colours, cleans the engravings, impresses the designs on the paper, and delivers them ready for the transferrers, in a silent and uninterrupted succession!

CHAPTER II.

SCIENCE OF MIXING.

SCIENTIFIC PRINCIPLES OF THE MANUFACTURE.—COMBINATIVE POTENCIES OF THE EARTHS.

THE Manufacture embraces the compounding of earthy minerals, likewise of metallic oxides, into ductile and colorific substances for the fabrication of EARTHENWARES, utensils receptive and retentive, of the different articles for the various purposes of refection and the toilet, and also ornaments, elegant vases, figures, busts, medallions, etc. The principle most interesting, and entitled to special attention, because it involves its perfection, being, to unite in the products the excellencies of wholesomeness, neatness and durability. Hence results the

Problem.—How the natural products, alumine and silica, in other and different proportions than at present adopted, can be artificially compounded to form other and better wares.

By determining all the conditions of this problem, chemistry will establish the processes in a constant method; removing whatever is indifferent or

detrimental, and as far as is useful introducing into others whatever has in one been proved advantageous. The silicates which Nature supplies are much exceeded in complexity by the artificial silicates which without any regard to first principles have resulted from the potter's syntheses, which in vain essays to equal the former. Still, as the formation of the latter, by compounding the materials agreeably to their respective properties and potencies, similar to equivalent and proportional chemical compounds, will ultimately render the fabricated wares incapable of improvement, for this state of simplicity and certainty our enthusiasm incites the hope, as involving important advantages to society. The scientific explorer of the less-frequented recesses of Nature has often, like the voyager when in search of unknown regions, approached very nigh, yet without having had the felicity to discover an interesting point; and yet numerous are the discoveries, many of them productive of momentous consequences to mankind, from experiments intended less for the pursuit of an important object, than for the indulgence of amusing curiosity.

Assuming that there exists, I have attempted to supply, the necessity to facilitate the Manufacturer's acquisition of accurate and extensive knowledge; to clearly direct him through the most intricate and perplexing mazes of all the distinctive properties of the different kinds of ware; determine the precise proportions of those materials which are the components of each body, glaze, and colour, and incite the emulation which will cause experiments for products similar to those most excellent; supersede vague incertitude and conjectural generalities; also the prevalent

prejudice in favour of *guesses;* exhibit which compounds are incompatible, unless one of the components is in the *minimum;* by well-determined results (explaining the refractory nature of each at a certain temperature, in the different ranges or *rings*, afforded by the potter's oven) supply means for comparing and verifying isolated or fresh productions, as well as the varieties of the series; arrange the species in that order in the scale of excellence to which each is indisputably entitled; distinguish their essential and mutual relations which determine their agreement; regard as of one species all those kinds which have common characteristics of quality and components; and, by its processes and determined calculations being restricted by scientific principles and mathematical precision, supply the best possible chance to improve the productions of Britain to the perfection and excellence of Nankin porcelain.

Results thus contemplated are no longer problematical; however, in bygone times they might reasonably have been questioned, when the Manufacture was but a traditional practice, and its fabrics coarse and mere blunges of the ingredients; when all the stoneware had a compact texture, and split on sudden rise of temperature; when the porcelain was incapable of bearing, without cracking, alternations of heat and cold; before Cookworthy had supplied the conception of a durable common porcelain, though his success scarcely experienced the encouragement he merited; or, were known the properties of steatite and magnesia to prevent or preclude fusion, yet not impart any colouring principle; or, those of barytes

to supply the place of saline fluxes; or, those of pumice-stone to resist any solvent of the varnish; or, the common porcelains of Champion and Turner had been proved refractory in the oven; or, the analysis of felspar had instructed us, from very common materials to compose it artificially; or, the productions of Spode had been investigated and recognised as a real porcelain.

The researches of chemistry are authorities for regarding the elements silica, alumine, and alkali in the following relations: the first, as most efficiently acidulant; by (electro-negative or) recipient potency, and its insinuative momenta, in various multiples of 4 it combines, and whatever other acid may be present, remains in combination with bases, in every mineral, to the highest (or electro-positive) active element, the alkali; the next, alumine, as neutral and convertible, receptive of many multiples of 4 of either or both of the others, with the former of which it more frequently and readily combines than with any other element; when mixed in water and left to evaporate, the atmosphere fails to separate them; yet when together alone, the most ardent temperature is not productive of vitrescence, the silica is devoid of adhesive potency, and at the temperature of the cream-colour biscuit baking, 40° Wedgwood, 4717° Fahrenheit, water remains present with the alumine. And the third, the alkali, by its peculiar supply of oxygen in raised temperatures, as a flux promotes the formation of all into a compact vitreous compound. This effect causes the first to be named by some writers the *vitrifiable earth*; also, because although it

readily combines with iron, its great difference from the substances named *metals* renders very difficult its assimilation.

Problem.—When held in solution by an aciduline or alkaline menstruum, are there any or what reciprocal combinative potencies between alumine and the other earths, magnesia, lime, barytes, and silica?

To solve this, the anhydrous earths used were prepared with every care to preclude the presence of acid or alkali, constantly remembering, that on mixing two solutions of compounds, their respective communicative potencies solicit those relatively receptive or quiescent (probably in other compounds agents, not patients as herein), and in the precise degrees of relative potency combine into two fresh distinct and separate compounds, possessing communicative potency to solicit further another proportion of the receptive elements and form a different compound. The great care and attention with which I endeavoured to obtain correct results, frequently when all my family were enjoying their midnight slumbers, and the agreement between them and those of celebrated analysts, induce the opinion that they approach as near to absolute truth as can be obtained from current knowledge of processes. I therefore with more confidence publish the results. In each experiment saturated solutions of the substances were filtered twice, and by evaporation concentrated to the specific gravity which had the ratio of the atomic weight.

The combinative potencies of alumine and of silica are great and equal; that of alumine exceeds that of magnesia, yet both are stronger than those

just mentioned; and those of alumine and of lime are comparatively weak.

The *modus operandi* of alumine soliciting silica to combination may be inferred. All minerals in which much silica is present, and only little alumine, on being completely fused with potash, then reduced to comminution and dissolved in muriatic acid, and afterwards treated with plenty of pure water, by a light flocculence insoluble in acids, indicate that silica had been present in the aciduline solution. But corresponding results are not presented on similar treatment of minerals whose components are much alumine and little silica. Fusion with potash equalises the tenuity of the particles of a mineral, and the mechanical separation of the silica present must be proportionate; but no experiment supplied results like those of the presence of alumine, as to efficient promotion of the chemical solution of the silica. Therefore, the solubility is determined by the proportions of the alumine.

In reference to alumine soliciting magnesia, current knowledge is only paucile. The potency is such that on being exhibited to the latter in any solution combination ensues, together they precipitate, and leave the menstruum again unappropriated; even the potency of potash on the former fails of its effects when the two earths have a determined relative proportion.

Process.—A solution of muriate of magnesia alkalinise with test 2—there will be a trifling precipitate of ammoniacal muriate of magnesia. Mix solutions of muriate of magnesia and muriate of alumine in excess, then alkalinise with test 2—all will precipitate, except the muriate of the test. Filter out, wash, and

evaporate dry the precipitate; next dissolve it in test 26, with test 1 alkalinise, and raise the temperature to 220° Fahrenheit, by which part of the alumine will be appropriated. The remainder filter out, wash again, and evaporate dry, and dissolve in test 26; the solution alkalinise with test 3, and the alumine precipitates, and must be filtered out, washed well, and dried as already directed. The process of boiling in potash, and precipitating by carbonic acid, repeat until all of both earths is obtained.

That alumine promotes the solubility of lime in potash is inferred from these facts: when lime alone is boiled in test 1, only a like quantity is appropriated to what would have been by an equal quantity of cold water without any potash; and the solvent power of the pure cold water is much greater on lime when alumine and potash are added and the temperature raised to 218° Fahrenheit.

In employing the potash as stated, considerable care was necessary to preclude the possible effect of the carbonic acid on the alkali itself as well as the precipitate. There was no precipitate obtained from mixing a solution of muriate of lime with one of muriate of alumine, or magnesia, or barytes, or strontia; neither from mixing one of muriate of magnesia with one of muriate of alumine, or barytes, or strontia; nor of muriate of alumine with muriate of barytes or of strontia; nor of muriate of barytes with muriate of strontia; nor of lime-water and barytes-water. But on mixing potash solutions of alumine and of silica, after 48 hours' repose a copious precipitate resulted; also, on mixing a solution of silica in potash, with lime-water, barytes-water and strontia-water.

The momenta with which the earths appropriate moisture from the atmosphere have been determined by Sir J. Leslie as—silica 40, alumine 84, pipe-clay

85, felspar 80, carbonate of magnesia 75, carbonate of lime 70, carbonate of barytes 32, baked clay 35, red-hot clay (cooled) 8. Of their retentive potency less is known; although, as already stated, at a temperature which fuses pure silver, 4717° Fahrenheit, alumine retains a portion of moisture; and when all is vapourised, and the element left pure, the loss is ascertained as 46 per cent.

The fact has been long known, that whenever three of the earths are present together, either partial or complete vitrescence ensues at 130° to 150° Wedgwood. Guyton states that he obtained a temperature which Saussure calculated equal to 1575° of this pyrometer [without mentioning his data for comparison], by a stream of oxygen gas on burning charcoal, and converted alumine into a white enamel, semi-transparent and extremely hard, so as to scintillate in collision with steel.

At a temperature equal to 150° Wedgwood the mentioned results were obtained: magnesia and alumine remained indifferent to each other's presence; alumine 1 + lime 2 remained a powder; A 1 + L 3 not fused; but these proportions, L 1 + A 2, L 1 + A 3, L 1 + A 4, were fused by the temperature which Ehrman obtained, by directing a stream of oxygen over burning charcoal. Silica 4 + barytes 1 gave a mass white and brittle; S 3 + B 1 brittle and hard; S 2 + B 1 porous porcelain; S 1 + B 1 not fused, yet hard; S 1 + 4 B intermediate between porcelain and enamel; S 1 + 3 B porous porcelain; S 1 + B 2 greenish-white porous porcelain; S 1 + B 1 a white hard scintillating mass, intermediate between porcelain and enamel. At 156° L 4 + S 1 powder,

L 1 + S 4 brittle, not melted. Achard is of opinion that for the compound to be vitrifiable, the earths must have the mean proportions, alumine 1, magnesia 2, lime 3; but when there is plus of magnesia, the temperature must be 166° Wedgwood. Kirwan is of opinion, that these proportions, A 3, L 2, M 1, also A 3, L 1, M 2, and A 3, L 2, M 2, form porcelains; while A 3, L 1, M 3, and A 3, L 2, M 3, form porous porcelains.

The imperfect knowledge possessed by persons who could give such guesses is to be regretted, for they are authorities on some important properties of substances. The earths under certain conditions of temperature, and the elastic pressure of the general atmosphere, have essential and reciprocal potencies, with definite momenta to solicit each other to combination, rendering fixed or concrete immutable numbers of the atoms of ultimate components; and hence ever invariable in each artificial or proximate compound, chemical, not merely mechanical. Analysis with tolerable confidence determines the precise number of atoms of each ultimate component present; but because current processes of synthesis fail to supply accurate and complete imitations, we remain unacquainted with the real cause of their combination in the proximate compounds. And yet none will question that immense sums to the Manufacturer would have been saved by the scientific solution of the problem, taking into the account the properties of the several materials, and the necessity of reciprocal action and quiescence during the manipulations and process of baking, what determined quantities of each will chemically effect the grand purposes of

which combination is susceptible, the acmè of perfection, a durable, excellent and beautiful ware, adapted for general utility. At present we are uncertain whether this combination is, or not, consequent on a principal component being infusible and insoluble; or, on temperature increasing the momenta of the combinative potencies of all, or of only certain of the components—of the silicic acid present with certain bases, A; and the metal, B, with the alkali of the glaze, D; or, of the silicic acid, A, and the alumine of the clay, C, with the metal, B, and the alkali of the glaze, D; or, whether is their true combination, ABCD, AB+D, ABC+ D, AC + BD, ABD + C, AD+BC, ACD +B.

The careful investigation and calculation, analytically, of the elements present in several of the recipes according to which are compounded the wares now fabricated, induce the following conclusions: Assuming the numbers assigned to the combinative potencies of the elementary atoms, p. 49, I find the composition of porcelain to be, in the mean, silica 2, alumine 3, and lithia 0·667, or $16 \times 2 + 24 \times 3 + 8 = 112$; likewise, that of the best flintware to be silica 1, alumine 4, or $16 + 24 \times 4 = 112$.* On the evi-

* Vauquelin regards sommite as silica 46 + alumine 49; and euclase as silica 22 + alumine 35; and reasons thus, 49 : 3·2 : : 46 : 3; and 22 : 3·2 : : 35 : 5·09. But what have we in this which we can regard as definite, 3 being the prime equivalent in the former, and 5·09 in the latter? Now, regarding as I do the combinative potency of silica as $4 \times 4 = 16$, and that of alumine $6 \times 4 = 24$, which reciprocally solicit each other, and likewise the other elements, I am agreeably surprised to find in the former the sommite $16 \times 3 + 24 \times 2 = 48 + 48$, the ratio being as 3 to 2; and in the latter, the euclase, $6 \times 4 + 9 \times 4 = 24 + 36$; precisely as ($16 + 8 = 24$, and $24 + 12 = 36$) $1\frac{1}{2}$ to $1\frac{1}{2}$.

dence of numbers, then, and of such easy numbers, we find an arithmetical solution of the problem of the equivalence of combinative potencies for the wares porcelain and earthenware ; a solution, to accomplish which, the endeavours of a mighty genius, Réaumur, were ineffectual, because not possessed of the facilities we enjoy ; a solution which is entitled to more attention than it has yet received, and whose corroboration will be by innumerable facts ; so that its verity, if not completely beyond all allegation of chance, has a probability of many millions to one, and every repetition becomes a further power of the series, and a closer approach to absolute certainty. The coincidence and harmony of the numbers are the more remarkable, because the effect of mere accident in the choice and manner of persons making their arrangements ; yet as far as indirect evidence can, they prove the possibility of the substances being very much similar in

Guyton tells us he "made, without kaolin, a biscuit having the hardness, semi-transparency, and grain of porcelain, by giving the proper degree of baking to a paste composed of 50 silica, 20 alumine, 24 magnesia, and 6 lime. I need not say that it would be very easy to employ the same proportions of silica and alumine, by choosing a good clay, without having recourse to the decomposition of alum for the earth." Mr. Billingsley, at the Nungarrow Manufactory, from Lynn-sand, potash, and other components, made a porcelain which as an artificial felspar has some excellence, and approaches nearest real felspar ; the expense certainly was great ; and only was his ware defective through his being unacquainted with the *principles* of combinative potency. This was a notable instance, how much the mechanical processes of pottery are in advance of the "work and labour of love" for public benefit —the science of chemistry, in regard to atoms. Of the components of the porcelain made at Lowestoft, prior to 1750, and also of that at Bristol, in 1800, I have failed to obtain information.

elementary proportions, yet different in requisite excellencies; while the best can be decided only by investigations originated by other considerations.*

* A perfect porcelain body and glaze can be obtained by properly baking the natural kaolin and petuntse, whose proportions are as previously stated, silica 64, alumine 24, alkali 12, or 60, 24, 16. Agreeably to this standard, we can compare all bodies; and, having their quantities stated, we readily ascertain their approximation to Nature. The mean of eight recipes for flintware is, blue clay 25, black do. 22, brown do. 18, China do. 16, flint 16; *i.e.*, silica 6372 ÷ 16; alumine 3223 ÷ 24; lime 8; iron 132·5; which (rejecting the spice of lime and iron) show 99½ doses of silica, and 134½ doses of alumine; or rather less than one-eighth above the mean 112 in 85. The mean of five soft porcelain recipes is, blue clay 20, China do. 40, grauen 28, flint 12; *i.e.*, silica 7204 ÷ 16, alumine 3071 ÷ 24; lime 13; iron 55·25; or one half-dose above 112 doses of silica, and one twenty-fourth of a dose short of 128 doses of alumine; only one-twentieth of an unit short of the mean 112 in 83. The mean of other five Bone China recipes is, blue clay 99, C. clay 321, grauen 315, bone-earth 354, flint 42; *i.e.*, silica 55731 ÷ 16, alumine 17487 ÷ 24, alkali 473 ÷ 8, lime 396; or two-thirds of a dose above 870 doses of silica, nine twenty-fourths of an unit short of 728 doses of alumine, and a mere trifle short of 60 doses of alkali, besides the potency of the lime, 32. There is one twenty-eighth excess above the mean of 112, in 661; I think there needs scarce mention, that these will be soft, fragile, and readily affected by sudden rise of temperature. The two recipes for porcelain, and the three for flintware, published by Mr. Lakin, have respectively, silica 24056, 45130, alumine 7024, 13850, alkali 1064, 3860, lime 384, 420; and silica 54300, 45800, 45300, alumine 20000, 16200 (the latter spiced with alkali from the grauen). They contain doses of silica, 376, 705, alumine 293, 577, alkali 133, 482; lime 12, 13; also, silica $848\frac{7}{16}$, $715\frac{5}{8}$, 708, alumine $833\frac{1}{8}$, 675, 675; and vary from the mean of 112, five parts of an unit minus in 290, $\frac{1}{7}$ plus in 564, $\frac{1}{4}$ plus in 663, $\frac{8}{13}$ plus in 553, and $\frac{3}{4}$ minus in 549. Several hard porcelain recipes give the mean, kaolin (green) felspar 35, C. clay 20, blue

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To the preparation of the clays, as a chemical process, great attention is indispensable, as well as to their intermixture with flint and the other components; for, although their causes are like those which produce other compounds, the effects are not precisely similar; for thereon depend the composition, aggregation, and texture of the wares, as proved by the fracture. While pursuing certain processes,

do. 15, cracking do. 10, brown do. 10, black do. 10; *i.e.*, silica 6000, alumine 3345, alkali 600, iron 122·5, three-fourths of a dose above 93 doses of silica, one-sixth of a dose above 139 doses of alumine, and 75 doses of alkali; and there is an approximation of $\frac{6}{17}$ plus in 88 to the general mean of 112. Moderately good ware was fabricated by Rivers and Clowes, Shelton, in 1820, from blue clay 697, brown and cracking 230, C. clay 174, flint 579; *i.e.*, silica 139518 and alumine 37443, a small fraction of an unit short of 2178 doses of silica, and 1560 of alumine, being 32 + to 22, instead of 32 to 24; yet the mean 112 is precise in 158. The relative quantities of the components of Champion's porcelain, fabricated at New Hall, Shelton, were stated as ball clay $1\frac{1}{2}$, C. clay 8, C. stone 10, bone-earth 16, ground with a frit of soda 1, C. stone 4. The alkali promoted the semi-fusion and translucence; and the elements being 1638, and 428, almost 16 to 4, a sixth of a unit minus the mean of 112 in 18. The rationale proves that the compound approximated the nearest to perfect porcelain of any at that day manufactured in Britain.

In this way readily is determined the probability of excellence in the results of combinations; and more so, could we ascertain the precise weight of each component in two distinct bodies, also their relative proportions and specific gravities after sustaining the same high temperature; and of similar substances subjected to other temperatures, and by difference of specific gravity, indicate; variation of products, suggest the cause and the efficient remedy; and apportion the components in the ratio of specific gravity; and other compounds be determined, either the specific gravity from the proportions of the components, or these from the other.

frequently do improvements suggest themselves, useful, because extending the practical results. That one kind of clay more readily mixes with water and appropriates more silicic acid from the flint than another, and therefore requires a different height of temperature for baking the biscuit, which is seldom accurately determined, has been long known, to the slip-makers especially. But the materials may not always be in the same state of composition in Nature, and their employment will cause difference in the biscuit. For the practice to be so tenaciously continued, of trusting for the quality of wares to the vague and uncertain proportions of watery mixtures of clays, and of flint, etc., by mere measure, and omitting their relative density prior to lawning into the slip-tub and kiln, argues disregard of the certainty of scientific pottery.

The recipient potency of the alumine present in the natural clays solicits moisture with great momentum from each substance in contact in which it is present, even to the amount of 20 per cent. ; hence on applying clay to the tongue, it quickly adheres. This appropriation of moisture is especially advantageous to the material, by causing a gradual disintegration of the mass during exposure to the alternations of the seasons, either at the wharfs, or on the Manufactory. The Manufacturer who has adequate capital finds his advantage in keeping a large stock, that it may be well-weathered ; and in his vaults a sufficient quantity of clay ready for the workman ; as there, after the heat of the slip-kiln has mechanically connected the particles of the plastic mass, the longer it remains the more important are the changes effected spontaneously

by the chemical potencies of the components. I have heard it several times mentioned, that the Jasper and other dry bodies made by Messrs. Wedgwood are prepared several months prior to being used. I am not able, clearly and with confidence, to determine whether the *green* state of the ware, after certain manipulations is, or not, really an invisible chemical process, because of the presence of water and vegetable particles (similar to decomposition of vegetable mashes by fermentation), in which are active and quiescent alike, silicic acid, alumine and alkaline earths. The earths fresh supplied from the mines form clay, of which the ware fabricated is defective, cracks, rifts while in progress, and decomposes afterwards. While the earths long exposed to the atmospheric changes, more disintegrated, readily mix with the water, pass through the lawns, form clays which the workman can use to his satisfaction, and the reflecting Manufacturer thus is led to cause only long-weathered earths to be formed into clays kept as long in the vault as is convenient for his capital, instead of incurring the sacrifices consequent on the articles being fabricated from clays taken into the work-room reeking-hot from the slip-kiln.

The fabrication of good ware requires careful selection of the earths for the body, to provide for and ensure exact coincidence of pyrometrical expansion by heat, between the biscuit and its vitrescent coating or glaze. By combustibles prevented from injuring the properties of the components, the baking must be at a temperature proper for those of the glaze to reciprocally solicit and be solicited by those of the surface of the biscuit in contact. The

purity of the components of the biscuit, the extreme comminution of those of the glaze, and the precise temperature to ensure their chemical combination, are essential conditions of the science of potting.

When there is excess of silica (called *over-flinting*), the deficiency of alumine leaves unappropriated that excess; and the pyrometrical expansibility differing in different parts of the same vessel, *rifting* ensues, or when the excess regularly pervades all the vessel, it precludes the proper adhesion of the glaze particles, and after the baking the surface is left dry and rough, similar to what is the state of ware on which the workman has applied the sponge too frequently and injudiciously to the surface. A like effect results when excess of lime is present. When there is deficiency of silica (*under-flinting*), the quantity of moisture present with the alumine, on being evaporated *cleaves* the vessel, or causes *cracking*. The silicic acid of the grauen also frequently appropriates alkali from substances with which it is baking, and leaves dull and rough what otherwise would have a fine velvet gloss.

While obeying certain laws agreeably to the dimensions of the articles, the great difference of component materials causes variation in the pyrometrical expansibility of bodies, which at varied degrees of raised temperature become not merely mechanically solidified, but chemically less susceptible of solicitation from acid or alkali. The surfaces appropriate or dissipate heat, and in proportion to their bulk retain it; and the mutability of temperature depends on the ratio the solid contents bear to the surfaces; the more extended these in proportion to

the bulk, the quicker will be the pyrometrical alteration ; as the temperature of the surrounding medium will be less efficient, the greater the bulk is in proportion to the surfaces. The flat and long articles have more extended surface in proportion to the solidity, and *vice versâ ;* in vessels of like figure their surfaces are as the squares, and their solid contents as the cubes of their diameters. In vessels of like shape and substance but different sizes, the capacity for heat is as the cubes, and the mutability of temperature as the squares of their diameters.

Bodies brittle, or devoid of flexibility, crack by sudden heat, because the unequal action of the particles in fixation of oxygen varies the expansion of the orbital spaces of their atoms ; and this variation creating opposition among them, the substance separates, and the manner is distinguished by the terms, *crack, rend, rift, flee, break ;* and a like result ensues whenever a body, whose particles are much separated by that expansion, is subjected to sudden great diminution of temperature. Very thin vessels, therefore, best bear these changes. Current knowledge fails to determine what arrangement of particles is the real cause of brittleness. Many a body which bears a very high temperature by sudden cooling becomes hard and brittle (as steel and glass), and often very inconveniently when they are required to be soft and flexible, and which latter can be secured only by *annealing,* or gradually and carefully cooling them in a period of time proportioned to their bulk and solid contents. The sudden contractile property of most metals is counteracted by their flexibility ; but although exceeding these in flexibility and

elasticity, glass is so peculiarly brittle, that to expand or contract with temperature applied annealing is indispensable.*

The potters of Bow and Chelsea, from compounding well-washed sand from Alum Bay, Isle of Wight, ground cullet, and pipe-clay, fabricated porcelain, which was covered with a glaze, chiefly of lead, which had considerable demand in the early part of the last century. The removal of the Chelsea establishment in 1748 to Derby, was the cause of alteration of the components, from which excellent ware is now fabricated. Of like components, with a little alkali, was formed the porcelain fabricated at the Worcester establishment, formed in 1751, by the enterprise of some of the clergy of that cathedral, and for many years the principal director, *sub rosa*, was Dr. Davies.

The attempts of the Staffordshire Manufacturers, about the same time, Littler, Yates, Baddeley, and others, to fabricate porcelain, completely failed, because of not understanding the chemical properties of the materials employed. I do not feel warranted in mentioning the information received of the proportions they severally adopted. But it seems proper to state, that their practice of forming the china

* The deficiency just mentioned would induce the supposition that glass is analogous to steel. Articles of steel, suddenly cooled from a high temperature, remain more expanded in surface than when, from like temperature, carefully protected while brought down to that of the atmosphere. Without the annealing process, the particles forming the external surface, and which suddenly cooled, would remain more contracted than those interior, and not adapted to their development, as less slowly cooled.

body of a frit, was suggested by the usual methods of the glass-makers, to prepare the materials for their glass pots, by rendering them opaque, yet not homogeneous, of strong adhesion as a semi-vitrescent paste ; the chemical combination of the silica, alumine, alkali, and metallic oxides being commenced, the carbonic acid and moisture being dissipated from the components, superseding their swelling when in the vessels.

The formation of porcelain results from the proximate chemical combination, by very high temperature, of an alkali with silica, alumine, and lime, in like proportions to those which Nature combines in certain species of felspar. The earths are rendered more refractory by their state of purity ; and the basis is a clay which bakes very white, while the other components promote incipient vitrification, forming a compound intermediate between flint ware and glass, yet infusible by the high temperature which renders the texture fine but compact, the fracture semi-vitreous, with translucence, a peculiar toughness, and perfect white tint after each subsequent baking.

The circumstance of only the felspar of Limoges being employed as the chief component of the Sevres porcelain, suggested the search for a similar mineral in Britain ; and in 1818, James Ryan, F.S.A., discovered it in the useless refuse of a discontinued lead mine at Middletown Hill, just entering Wales, from Salop. By employing the greenish or slate-grey felspar (which I distinguish by the name *kaolin*) as a component of the body, and the brown lemon, *petuntse*, the more fusible because of the presence of two additional doses of alkali, as chief component of

the glaze, British porcelain, from its state of inferiority to those of the European continent, enjoys a new and important era, and excellence and superiority over any other, rapidly approximating to perfection—the *ne plus ultra* of the Art—which probably will result from the increasing researches and extended views of mineralogists and chemists in the present century.

In forming the best *hard porcelain*, part of the components of both body and glaze are formed into frits, and then with the other components, earths, and alkali, and oxide, ground very comminute prior to being evaporated on the slip-kiln, or used in the dipping-tub; the finer the grinding, the more beautiful will be the ware. The biscuit is translucent, much like well-ground glass; in very thick plates (two or three lines), there is merely a shade, free from a brown or muddy tint, while in others very thin there is a distinct but colourless figure. I need scarcely mention that the proportions of the components in both are carefully determined. In using the minimum of kaolin, translucence is obtained only by extremely high temperature, that would affect the shapes of the articles was the maximum employed.*

*The progression towards perfection, in the transatlantic productions, is very rapid, according to Professor Silliman: "The porcelain of the Philadelphia Manufactory is very beautiful in all the principal particulars; in symmetry of modelling, in purity of whiteness, in the characteristic translucence, in smoothness and lustre, and in the delicacy and richness of the gilding, and of the enamel painting. That it rivals the finest productions of Sevres itself, it is not necessary to assert; but it certainly gives every assurance, that if properly supported, it will not fail to meet every demand of utility and taste, which this great and growing country may present.

Occasionally this last effect is counteracted, and the contractile property equalised, by using steatite or soap-rock, fusible readily with silica and alumine, partially with either, but not at all used alone. Because of the failure of some establishments which commenced the Manufacture of *hard* porcelain, an opinion has been current that it cannot compete with that of the *soft*, though the proofs of its rivalry are obvious in the increasing prosperity of some other establishments.

As in all reasoning we must proceed from what is known or determined to what is unknown or required ; there is indispensable in each proposition one subject whose determined potency adapts it for a standard of the calculations. Throughout the whole, silica has been regarded as possessing this readily-determined potency. The reduction of artificial silicates to their equivalent components was an important problem, that might have remained probably a long time without solution, had not circumstances of a peculiar kind led me to consider its importance. With the numeral 4 as the index of combinative potency, I have been enabled, with considerable accuracy, to determine the equivalent ratios of many compounds ; and I may here assure the reader, that on the same principle, with the aid of the Tables in Part III., he will himself readily accomplish the determination of the components of any compound he chooses to fabricate. And the respective properties of the ingredients will be more clearly comprehended from the results.

It is proper to remark, that I am persuaded when chemical researches have been more steadily

pursued in reference to this interesting Manufacture, so that the accuracy of reasoning on the combinative potencies of the elements distinctively can be with confidence employed with reference to the artificial compounds, we shall find that the respective ingredients do not reciprocally combine in an indefinite degree, or by imperceptible gradations, but that they proceed, *per saltem*, regularly, in definite proportions with reference to being multiples of the first potency, and that uniformity exists in the resulting compounds only when there is precise correspondence in the proportions. This view is a rational sequence of the principle that combinative potency in every instance may be modified by a second or third multiple of one of the components, as well as by raised temperature, and other adventitious conditions of the compound.

There remains little likelihood of the Art ever again supplying a possessor of the imperial purple, as in the instance of Agathocles; but it can boast an incomparably greater number, than can crowns or coronets, of *honest* men, "the noblest work of God:"

Among the ancient royal names
Agathocles I gladly find;
Pre-eminence he chiefly claims,
For virtues of the noblest kind;
To deck his board with bowls of gold
The usage of the times required;
But he, his father's earthen mould
With filial fondness most admired;
The Potter's vessels there had place,
And with the gold the tables grace.

TESTI, the Italian Horace.

CHAPTER III.

BODIES.

In this Manufacture the word Body signifies the plastic compound of materials, in the moist state named *Clay*, because then workable; and also in contradistinction to the fusible covering or *Glaze*. The combination of the materials, however, differs with almost every Manufacturer, who seeks to distinguish his ware by some supposed or real excellence.

On the principle promulgated by that persevering and intelligent chemist, Guyton Morveau, only *Stone Ware* and *Porcelain* are entitled to the name Pottery. And he further indulged the opinion, that the public health will be best consulted by substituting a supply of porcelain in the place of common earthenware, and such as is required to bear the fire, delft and flintware, in reference to economy, neatness, wholesomeness and durability.

Such an entire change of system, however, is superseded by scientific potting, which regards the reciprocal potencies of the materials, and always finds, in compounding several together, their equivalent numbers, or multiples thereof, are present when-

ever they chemically combine, not mechanically mix; and consequently that the sum of the equivalents will denote the proportions of combinative potencies.

Problem.—It is required to combine a body, either opaque or translucent when baked, which shall be so compact, and durable, and receptive of the particles of glaze and colours, as never again to separate (craze) by action of other substances, or change of temperature.

The *Common Red Ware* is formed of materials prepared by a method practised prior to any historical records. A small tank is formed, about two or three feet square and deep, at the corner of a second, in size in accordance with the conveniences supplied by the spot. The bottom of the larger has fine sand strewed over it in a thin stratum, and after the clay has been violently agitated in the smaller tank, in water, to loosen and allow to subside portions of gravel or pyrites present, the mixture is passed through a hair-sieve upon the larger, till there is a covering of about four inches, when the mass is left to be evaporated by the atmosphere; and hence the tank is named the *Sun Pan.* Over this stratum a succession of others is formed, till the whole is more than a foot thick of clay, and then it is removed and slapped for use. The biscuit state of this ware, because baked only slightly, and just to sustain the transition from heat to cold, is very porous. The presence of oxide of iron, also of the components of the coating or glaze—sulphite of lead,* and oxides

* The fact is lamentable, though scarcely noticed, that in fabricating some of the vessels for domestic purposes, materials are employed which are extremely deleterious. Lead and its oxides

of manganese and copper or iron—prevents its being sufficiently refractory to sustain a high temperature, and its glaze is therefore very fusible.

admitted into the stomach in very minute particles and quantities injure the important blessing, health, of our fellow-men; gradually affecting the organs of digestion, there is insensible operation of the poison, with consequent emaciation, cholic, convulsions and diarrhœa. The men who dip common ware often have most of the systems of the *Painter's Cholic*—progressing from dry belly-ache, eructations, slight nausea, thirst, anxiety, quick pulse, obstinate costiveness, vomiting of acrid bile, shooting pains from the navel to each side, spasms in the intestines, the belly highly painful when touched, and the extremities tending to paralysis. Even when these do not terminate fatally, too frequently they cause palsy, contractions of the hands and feet, inability of the muscles to perform their office, and in this miserable state the patient lingers out many years. Those who use such wares thus become the victims of their own ignorance, and of the imprudent avarice of the Manufacturer, who should understand that, while he never ought to be either the dupe of cupidity [or the victim of ignorance], it is no innocent matter to the trade, as well as society, for any productions to prove valueless; the stigma affects the worth of all ware; neither should he, for economy merely employ in body or glaze, or both, materials which more readily bake; for ultimately he would be benefited, were all vended wares to possess certain relative perfection and excellence. When the baking merely agglutinates the glaze to the body, the whole of it may be divided and appropriated by the liquids, aciduline or alkaline, which come into contact; even very hot water has almost equal effect; the crazing process commences; the ware, whatever its appearance, speedily fails in using, because not being properly baked, the fabric is readily destructible by rough usage. The difference in the pyrometrical expansibility of body and glaze cause the latter to separate minutely, not by the naked eye perceptible when new, but plainly so when washed after containing hot, greasy liquids. The danger to the public health, from employing such defective fabrications, is equally imminent, although insidious and concealed.

The *Delft Ware*, so named from the town in Holland where it continues to be made (and frequently applied to what the Manufacturers call *Cream Colour*), on its introduction was a grand invention, because of the beauty of its glaze; and it is known to have suggested the Staffordshire *White Stone Ware*, from which there was an easy transition to *Flint Ware*. The Delft body is a compound of natural clays, as no one alone possesses the properties indispensable to the fabrication of suitable ware. The workman regards all clays with excess of alumine as *too fat*, because vessels fabricated thereof, whatever their substance, would require a long time to dry for baking, fail in their shape by sinking down, and crack by the evaporation of the moisture present; and that as *too poor* in which is excess of silica, or sand, or marle, and which therefore will not retain the shape given by the operatives. To diminish this fatness without affecting the ductility proper for the manipulations, marle or sand is carefully mixed, and its silicic acid is appropriated by the alumine, whose particles being thereby kept asunder, the requisite evaporation proceeds without the vessel sustaining injury by sinking or cracking. *Delft* ware, consequently, is defective; it is baked slightly, and only sufficient to preclude sinking from the temperature requisite to combine and vitrify the components of the glaze, which would be injured by a higher temperature. With two or more clays are mixed some sand, or marle, whose lime renders the body compact from the semi-fusion with the glaze, which on this ground has a white and glossy appearance. Yet the biscuit and glaze suffer from sudden alternations of temperature, and appropriate grease

from hot greasy liquids, because of its soft nature, composed of vitrified lead and silica, by tin rendered white and opaque. M. Bosc d'Antic gives these proportions for common: 46 lead calc, 6 tin calc, 40 fine sand, 8 sea-salt; and for the best, 38, 10, 40 and 12 respectively. Pajot de Charmes says that *Salt* thrown into the oven while pottery is baking forms a glaze, and that it improves the whiteness and clearness of glass. Sulphate of soda will not succeed with sand alone, but equal parts of sand, carbonate of lime, and dried sulphate of soda, formed a clear, solid, pale yellow glass.

Porcelain.—*Hard*—the finest and most valuable has these essential and indispensable properties: The component earths are combined in such relative proportions, that proper baking renders the mass translucent, firm, hard, dense, durable, and sonorous when struck with a hard body; a white colour approaching the tint of milk; a grain fine and close; texture compact, intermediate between the closeness of glass and the obvious porosity of the best flint-ware; fracture semi-vitreous, and will sustain without injury sudden alternations of high and low temperature; the presence of an alkaline component possessing the quality of a flux relative to the others, most economically brings all of them into a state approximating to fusion, and in the kinds varies the translucence; which foreigners try by every method to decrease, and the English Manufacturers seek to increase, while preserving the fine close grain. The biscuit must be adapted to readily absorb water without injury. This is covered with a glaze, clear, white, transparent, indestructible by acids, or alkalies, or

temperature, beautifully fine, to the touch smooth, and appearing soft like velvet, rather than lustrous or glossy like satin. When first applied to the ware, the water readily permeates the pores, and on the surface the thin coating of components quickly dries into a solid shell uniformly thick over all the parts, and sufficiently firm to bear handling without being rubbed off during removal into the seggars.

Soft.—The body is less dense, yet sonorous, white, translucent, granular, and very fine porous fracture, harder and less brittle than glass, moderately hard glaze, and will sustain considerable alternations of temperature.

The following comparison will probably supply useful information, and gratify the curiosity of the scientific chemist :—

	Staffordshire		Berlin	Vienna	Sevres	Dresden	Nankin
	Hard	Soft					
Silica	0·750	0·610	0·590	0·640	0·696	0·602	0·660
Alumine	0·096	0·250	0·340	0·250	0·250	0·320	0·180
Alkali	0·030	0·020	0·020	0·096	0·020	0·020	0·120
Lime	0·012	0·050	0·008	0·010	0·018	0·008	0·040
Magnesia	0·050	0·050	0·027	0·0	0·	0·007	0·
Water	0·050	0·010	0·012	0·010	0·040	0·040	0·
	0·988	0·990	0·997	1·000	0·998	1·000	1·000

Stone China, in imitation of the Oriental, is very thick, strong, semi-translucent, vitrescent, coarse texture, granular fracture, durable, but with a very soft glaze ; and by the addition of a portion of slag of the iron-smelting furnace, is formed the kind called the *Patent Ironstone China.*

The *Dresden Porcelain,* equally refractory in the baking as is the Japanese, which it excels in

whiteness and sonorosity, according to the opinion of the English connoisseurs, is firm and compact, and will sustain without injury alternations of temperature; and has a fracture not granular, but uniform and semi-vitreous, similar to white enamel. Its fusible components are the tarso, or felspar gravel, from the River Po; and its infusible is the clay from Aué, near Sneeberg. This clay, by Rose's analysis, has silica 52, alumine 47, iron 0·33. These certainly are not chemically equivalent, but possibly some error exists in the analysis; however, the near coincidence between the two numbers, thirteen fours and twelve fours, and the proportions in other clays, is calculated to cause the reflecting mind to regard the principle of combination as more extensively applicable than was previously supposed. The materials are combined in proportions, at present carefully concealed. The fusibility of the felspar gravel promotes the density and smooth peculiar lustre, while the clay secures its firm solidity and beautiful white appearance, and together there is regular contraction during the baking process. Of the processes we only know that the clay is prepared at the equinoxes, when the rain-water used for levigating the earths and mixing the body is of a certain temperature, and conjectured to be less adulterated with tralatitious ingredients. By keeping long the prepared clay previous to its fabrication into ware, a kind of fermentation ensues, which destroys any combustible material present, and prevents discoloration of the biscuit. The ware is baked with well-dried white wood, whose alkali combines with that of the felspar in forwarding the vitrification of the ware.

The Oriental porcelain is of three qualities; viz., BODY—*best*, equal proportions of kaolin and petuntse, with a component kept secret; *second*, kaolin 40, petuntse 60; and *common*, kaolin 25, petuntse 75. GLAZE 1, white petuntse 100 parts, sulphate of lime calcined and pulverised 1 part mixed with 100 lime rendered more alkaline and caustic by being three or four times calcined with wood in a certain proportion; for 2, the like with additional sulphate of lime. Then for best glaze, liquids of equal density are formed of 1 and 2, and ten parts of the former are added to one of the latter. The *Clay* is prepared by a laborious method. In paved tanks or pits of several yards dimensions, men tread together the component earths, similar to the English practice of plasterers treading hair-mortar, until the whole mass is tawed or kneaded to a proper consistence, which is regarded as indispensable to the fabrication of fine ware, as thereby almost every particle of heterogeneous substance present, whether by accident, or adulteration at the quarries where the cakes are first formed, is discovered and abstracted; as it has been proved that air-bubble, hair, or sand will spoil the vessel in which it occurs. Portions of the well-tawed mass are then manually rolled various ways on slabs to prepare them for subsequent manipulations. For the *Glaze*, the powders of the petuntse and sulphate of lime, in proportions above stated, are mixed in water, and, in the technicality of the art, called an *oil*; calcined carbonate of lime is slaked by sprinkled water, and the powder is strewed over fern, and thus again burned, which latter process is repeated thrice for the best glaze; and to this is added 1 per cent. of the

calcined sulphate; the liquids are then mixed as 90 of the former to 10 of the latter. This additional alkalinity not only adapts the glaze the more readily to fuse, but also more efficiently to solicit to combination the surface of the ware with which it is in contact.

The Sevres Porcelain excels all the others manufactured in France, notwithstanding the great improvement which has been made in them; and the fact that the trade can be followed by the sons of the aristocracy, without derogation; with all the other properties of *real hard porcelain*, in compactness, etc., as already stated, and a glaze, fine, colourless, and transparent, its fracture has more the appearance of very fine lump-sugar, than a vitrified durable substance. The Materials for both Body and Glaze are the (Melting Spar) felspar and clay from St. Yrieux la Perche, near Limoges, 400 miles from Paris, and some from Alençon, and from near Bayonne. They are prepared for the Manufacturer (as in China) on the spot where quarried; and, being delivered in a state ready for mixing together, a much less working capital is required than for the purposes of the British Manufacturer. The two Recipes handed me by a friend who had visited most of the French Manufactories give: Body—Felspar 67, Clay 33; and Clay 66, felspar 15, sulphate of lime 9, carbonate of lime 6; baked ware in a comminute state, or semi-fluid 10; *Glaze*—felspar 85, alkali 15; felspar 75, gypsum 12, ground ware 12, alkali 1. The intermixture of ground shards is constantly practised, and whenever there is a deficiency of supply, an artificial substitute is provided, a number of thin pieces resembling stilts are

fabricated, baked well, and ground to an impalpable powder. I met with the senseless remark of a writer, evidently ignorant of the resources of the French, that, because their nation does not supply a natural porcelain clay equal to that of some other of the continental states, the Sevres Manufacturers despair of making their ware equal to those of King-te-ching, Saxony, and Vienna. The progress of chemical and mineralogical science warrants a directly opposite conclusion.

The porcelain of Vienna, Frankendal, and other places in Germany, is formed of the tarso and clay from near Passau ; but there is such variations in the proportions or processes, or both, as to cause great difference, as well from each other as from that of Dresden. And equal dissimilarity exists between them and that of Berlin formed of the tarso and clay from the valley of Gatach, above Haussach, in Wirtemberg ; also, those of Villaroy and Orleans, of Naples and Florence, which last possesses many of the excellencies of the best Oriental wares.

The Vienna hard porcelain has present much silica, little alumine, and very little lime. The soft much lime, sulphate or carbonate, or both, and even soft felspar, and a spice of alkali to economise the fuel ; and because it will not sustain the temperature requisite to bake the felspar glaze, that employed is softer, yet has a smoother appearance when baked.

Recently has been used in German porcelain carbonate of barytes, or of lime, and little alkali, potash, or soda, for the glaze ; and, for economy of fuel, also to secure the solidity by semi-vitrescence, and increase the translucence, sulphate of lime is introduced ; these alkaline earths and the silica vitri-

fying at the temperature mentioned, page 177. The first baking is at the temperature 62·77 Fahrenheit, or 40 Wedgwood, or that of baking Delft ware, merely to evaporate the water present with the earths. The ware in this state is very brittle, porous, has a dull grey colour, and little weight, much similar to the wine-cooler or alcarazza, and is ready for its coating or glaze. This is of components readily fusible, because of the necessity of differing from those of the biscuit, which should be refractory alone, and only semi-fusible with the covering; because was this to soften while the glaze is baking, the fluxing potency of its components would solicit those of the biscuit, and there might result the disaster of the ware sinking under its own weight, probably destroying the shapes of vessels, and the fine forms of figures. The ware is first dipped into an alkaline ley, then partially dried, and dipped into a fluid of felspar and vinegar, then dried, placed in the (gazettes) seggars and baked 30 to 36 hours.

In mentioning the relative proportions of the components of porcelain, and also of other kinds of bodies, I wish to be understood, that the following are of general utility; and when they are compounded as directed, the results will be satisfactory :—

HARD PORCELAIN.—FRITTED BODIES.

1. Kaolin 75, sal ammoniac 2, borax 23; frit twenty-four hours in a kiln; or, if fritted in seggars. let them be lined with Lynn sand 64, dry flint 36 mixed well together (instead of *flinting* the seggars, as is usual) and no loss will ensue, when the frit is picked. For

Body, Grind very well together, frit 45, China clay 40, ball clay 10, old clay shavings 5.

To every hundredweight ½ oz. of zaffre.

2. Kaolin 70, borax 20, nitre 5, sal ammoniac 5, frit twenty hours. Grind for *Body*, frit 45, flint 5, China clay 40, brown clay 5, shavings 5.

3. Kaolin 60, borax 25, flint 5, nitre 5, sal ammoniac 5. Grind for *Body*, frit 50, China clay 35, ball clay 5, shavings 10.

4. Kaolin 75, borax 20, nitre 2½, sal ammoniac 2½. Grind for *Body*, frit 60, china clay 30, shavings 10.

Raw Bodies.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Kaolin	55	50	30	50	40	40	50	54	50	56	52	46	45	30	30
China clay	20	30	22	30	30	37	20	20	25	36	32	25	30	30	30
Ball clay	10	5	20	...	10	10	10	10	8	...	10	10	10	10	20
Shavings	10	10	18	14	10	7	15	10	12	8	6	13	10	15	10
Flint	5	5	10	6	10	6	5	6	5	...	..	6	5	5	10

Here, as in other pages, will be seen how much practice is in advance of theory in the Art of Potting. The fact was often observed, that, although the slip-maker might most carefully obey his instructions, and mix the precise proportions of the components strictly in accordance with the best methods, and the clay itself fabricate ware of much excellence in biscuit, yet it could not be used by the workman, with the usual labour on his part, and to the advantage of the Manufacturer, because so very short or deficient in the adhesion of its particles, as not to hold together during the proper manipulations ; thus the *clay bat* could scarcely be properly beaten, and even when so, it would scarcely bear lifting from the block to the bench and mould. This annoying defect cannot be remedied by any theoretical remarks current in the chemistry of atoms, and only practice could suggest an efficient remedy. Economy of

materials causes a mixture of the fragments cut off the vessels by the turner, etc., and of fresh materials, in the slip-tub; and the presser had noticed an advantage in using such clay, by the additional quantity of sound vessels fabricated from a given weight, than from clay made wholly of fresh materials. Thus originated the opinion, by experience verified, that a body once worked will amalgamate with like components fresh introduced, and the whole be more readily receptive of the manipulations than entirely fresh compounds; and hence the utility of introducing shavings into the China body. Sometimes only shavings of the flint ware best printing body are employed for ball clay, with the other components. When the Middletown Hill felspars were first employed by Mr. Spode, a clay was formed in the usual manner, then the thrower formed strong thick vessels, left them to the green state, and the turner cut all up into very fine shavings, which in suitable proportions the slip-maker introduced into fresh mixtures, from which he made clay for the best porcelain, which answered the workman's purpose. The continuance of the clay in the vault for some days, or weeks, if convenient, will effect an intimate union of particles, which exceeds any produced by mechanical pressure; and every bubble of air is expelled by frequent slapping and working before either the thrower or presser will form his vessel; as, if present, expansion in the baking would fracture the article.

Porcelain biscuit much resembles fine statuary marble, and its surface likewise is without lustre. Hence the vases, figures, etc., fabricated by the

continental and English artisans, have much beauty and elegance; and in accordance with the quality of the components, the biscuit more or less exhibits the elegance of the workmanship; and the artist having increased the adhesion of the clay by some mucilage, starch, gum, etc., baking increases the beautiful appearance of all the sharp and clear edges and lines, like to fine sculpture, and not possible for glazed articles to exhibit.

I am not aware of any announcement of a porcelain whose body and glaze are so homogeneous as to save the extra labour and fuel by *needing only once baking*. Such is the difference in the components of the bodies and glazes of British porcelains that were the vessels to be dipped in the glaze liquid prior to being once baked, the water in permeating would destroy the adhesion of the clay, and the least disaster would be a shrinking of the shape of the article; and also, the different contractile properties of biscuit and clay not being provided for in the glaze, the portion unappropriated by the surface of the body would remain in ridges. It is proposed to take well-ground kaolin 30, China clay 50, native phosphate of lime 6, sulphate of barytes 14; grind twelve hours, evaporate into clay, and this the thrower and turner must form into shavings, as already stated, to be again ground in the proportions of 80 to 100 per cent. of fresh materials. Of this latter clay must the vessels for sale be fabricated; and, while each is on the lathe, the turner must apply (as for dipped ware), by the blow-pipe bowl, a liquid of glaze components—best petuntse 60, borax 16, carbonate of barytes 16, nitre 4, salt 4; or,

75, 10, 10, 5, 0; and when moderately dry, wash the inside with the liquid, and dry the whole ready for the seggar and baking.

SOFT PORCELAIN.

We may indulge a smile at the credulity of those persons who assign the introduction of bone earth into the body of soft porcelain to the following derisive remark of a Chinese potter: "The Europeans must be a wonderful people, to go about to make *a body*, whose flesh was to sustain itself *without bones*." For the fact was obvious in cupels, that at a very high temperature bone earth forms a white opaque enamel. The phosphoric acid present also will blanch any particles of oxide of iron in the clays used. These two properties render bone useful in soft porcelain.

Being readily solicited by alumine, and even as a hydrate, soliciting moisture from the atmosphere, and at raised temperature decomposing glass or porcelain, need we wonder that the quantity supplied by the bone earth renders the porcelain very soft. Equally will *Fluoric Acid* solicit silicium, or boron, and form a salt soluble in water; hence its decomposing potency on every glaze with which it is in contact.

A soft porcelain, translucent, brilliant, very white, but light, frangible, and easily injured by changes of temperature, is formed by compounding calcined bones, little gypsum, with grauen, China clay and flint.

The bones for the bone earth should be obtained as fresh as possible, and completely divested of all gelatinous particles; for the lengthened boiling will not effect this, yet injure the calcareous portion, and any particles left in such bone earth, not being receptive of those of the glaze, when such porcelain is enamelled or used, the glaze separates, and the ware is disfigured with black specks. A substitute for bones, and requiring not one-eighth of the weight, will be found in the native phosphate of lime, of a light-brown colour, in immense quantity in the county of Antrim, Ireland. The gypsum may be deprived of its water of crystallisation and translucence by calcination, and even by high temperature formed into an opaque milk-coloured enamel; but, as in the one state it will solidify by soliciting water present, and never is entirely indifferent to the presence of moisture, I regard it as demanding more attention in using it, than is repaid by any resulting advantage.

The *Soft Porcelain* formed of a *Fritted Body* has more firmness and greater density than the kind formed otherwise. The process is an excellent chemical lesson, which needs only to be well conned and steadily pursued, to ensure many advantages to the Manufacture. The frit is usually ground very fine, and then mixed with the proper earths.

1. Grauen 40, bone earth 40, cullet 20, frit twenty-four hours, and grind. For *Body*, Mix frit 70, China clay 20, blue clay 10. Stain with zaffre blue.

2. Grauen 50, bone earth 30, flint 10, cullet 10, grind. For *Body* Mix frit 65, China clay 20, brown clay 10, flint 5.

3. Grauen 50, bone earth 30, cullet 15, borax 5, grind. For *Body*, Mix frit 50, China clay 35, blue clay 5, flint 10.

4. Grauen 30, flint 25, cullet 25, lime 8, salt 4, borax 8, grind. For *Body*, Mix frit 40, China clay 48, blue clay 12.

The chemical combination of lime and silica by very high temperature had long been demonstrated in the fabrication of glass less liable to flee or crack from sudden and great changes of temperature than that from which lime is excluded. This combination is even more intimate when chloride of sodium is present; and hence the marle of the *Crouch ware* was useful in assisting the formation of the salt glaze. Whenever lime 25, flint 50, clay 25, or lime 48, flint 40, clay 12, are together at a high temperature, perfect fusion ensues; but the fusion is only partial of lime 25, flint 75; and lime 20, flint 80. Because of this property, porcelain with a minimum dose of lime as a component, while moderately firm and compact, is less refractory at high temperatures.

A soft porcelain (with many excellencies of the definition, and which without wauving requires baking at a high temperature, but has little cohesion and requires much care in working) is formed (says Mr. Brongniart) of this *Frit:* nitre, soda, alum, gypsum, sand and salt; for the *Body*, mix frit 75, clay 25. The proportions are not stated, and the possible mixtures may be in arithmetical progression to the number 720. This body is almost opaque; its glaze has plus of lead, and is very transparent, yet adapted for enamel colours.

Raw Bodies.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Bone earth	40	46	60	50	20	28	25	29	46	42	30	28	28	36	54
Grauen	20	18	16	8	40	30	25	35	25	20	20	35	30	20	16
China clay	25	20	20	25	20	20	16	16	20	25	30	18	20	24	20
Blue clay	4	4	4	4	...	10	15	10	...	...	10	8	12	...	...
Flint	6	...	...	3	10	5	9	5	...	5	5	6	..	10	...
Shavings	5	12	...	10	10	7	10	5	9	8	5	5	10	10	10

The following are the components of the French porcelain made at Chantilly: Limoges felspar 14, porcelain clay 60, carbonate of lime 6, sulphate of lime 10, ground shards 10; glazed with felspar 75, sulphate of lime 13, ground shards 12. A recent French patent directs—Clay 20, oxide of bismuth 40, ground shards 40, without any glaze. The Corsican porcelain has—felspar 40, clay 40, amianthus 20; and it is extremely light, yet little frangible, and will bear great and sudden alternations of temperature.

Stone China.	1	2	3	4	5	6	1	2	3	4	5	Ironstone.
Grauen	48	50	42	48	35	38	26	26	30	30	25	
China clay	27	38	25	30	30	32	20	26	10	5	15	
Blue clay	18	5	20	14	20	20	10	10	30	35	25	
Flint	7	7	13	8	15	10	16	16	5	...	15	
							28	22	25	30	20	Slag, ground.

DRY BODIES.

So named because without glaze are intermediate between porcelain and flint wares, partaking the properties of their biscuits. They are different in qualities and colours, and their value is enhanced by their employment to fabricate articles of taste and luxury rather than of general utility. They include the kinds: Chemical Utensils, Stone, Jasper, Pearl, Cane, Drab, Red, Black Egyptian, Fawn, Brown, Sage, etc. Several are so compact

and vitreous in biscuit, as neither to appropriate nor need a coating or glaze; yet their surface presents minute pores, as though gas had thence evolved during the baking. The *Jasper** and *Pearl* have usually much embellishment; and the elegance of the decorations is preserved in the sharp, prominent outlines, which would suffer in the ratio of the thickness of glaze applied. The *Red* is used for *Alcarazas*, *Buxaros*, or *Demi-Johns*, large porous vessels to hold water, yet admit a wine bottle into the cylindrical part, the outside usually having additional points of surface exhibited in the fruit and foliage decorations. They were invented and are much used in Spain. They are fabricated of clay, compounded of flint 36, and red clay or marle 56, brick clay 8, which are worked together with a weak salt ley; both of whose components being dissipated by the slight baking, the vessel is porous, and yet the whole has adhesion which sustains without any injury the continued oozing of the water through from the inside. These vessels are saturated with water, and then filled to the brim, and if a full bottle be therein, the temperature of its liquor will soon be brought low; it being a property of all substances to communicate

* I do not recollect hearing why this name was imposed. The *Pearl* was in consequence of the peculiar whiteness of the ware when first offered for sale. The *Porcelain Jasper* of Nature is in colour grey, yellow, or blue; with vitreo-resinous lustre, opaque, hard, and easily frangible, supposed (by Werner) a slate clay, by natural galvanism converted into a kind of porcelain; Link mentions that it melts into a white glass with the blow-pipe; and Rose gives its components—Silica 60·75, alumine 27·25, magnesia 3·00, alkali 3·66, oxide of iron 2·50, loss 2·84.

their atomic motion to all others in contact, with a facility in accordance with the number of surrounding points presented by the roughness of the surface; and the atomic motion of the water being diminished by the action of the surrounding atmosphere, as it evaporates through the pores, whatever water remains therein will soon be almost as cold as ice.* The practice prevails among those merchants who traverse the Arabian deserts. The bottles of water are wrapped in wet cloths, which are carefully kept wet, and the evaporation resulting keeps the water at a temperature most grateful to the palate.

* The difference of taste in the usage of wares for domestic purposes will readily suggest itself to the reader who compares his own experience with the following facts, extracted from a volume by MRS. MEER HASSAN, an English lady married to a Mussulman of Lucknow: "In the zeenahnah (lady's apartment), *china* or *glass* is comparatively little used; but the *common red earthen* katorah (or cup shaped like a vase). China bowls, basins, and dishes are used for serving many of the savoury articles of food in; but it is as common in the privacy of the palace as in the huts of the peasantry to see many choice things introduced at meals *served up in the rude earthen platter*, many of the delicacies of Asiatic cookery being esteemed more palatable from the earthen flavour of the new vessel in which it is served. I remember feeling some dissatisfaction at the rude appearance of the dishes containing choice specimens of Indian cookery which poured in on my arrival. In my ignorance I fancied that the Mussulman people must fear I should contaminate their China dishes; but I soon found that *brown earthen platters* were used by the nobility from choice, and the viand would want its greatest relish in *China* or *silver vessels*. China tea sets are rarely found in the zeenahnah, tea being used more as a medicine than as a refreshment. The ladies must have a severe cold to induce them to partake of the beverage even as a remedy, but by no means as a luxury."

CHEMICAL UTENSILS.

THE purposes of the laboratory render indispensable vessels of earthenware adapted to sustain, uninjured, the action of different powerful agents. The ware employed bears the name of the first maker, WEDGWOOD, among the chemists of Europe; and his grandson, the younger Josiah Wedgwood, has brought to the improvement of the ware adequate practical experience and great chemical knowledge. As most *Chemical Utensils*, on some occasion or other, are required to bear, without failure, considerable rise of temperature, they should be refractory at any degree usually and easily obtained, and continue uninjured by any sudden alternations thereof, as well as from saline or other compounds, in solution or fusion. We cannot preclude silica from all chemical action of such compounds; but this according ever with the number of points in the surfaces in contact, opportunity for destructive attack will be in the ratio of the comminute state of the silica. The principle is to preclude *cracking*, by apportioning the components, so that any slight excess of refractory or fusible may be provided for, and the whole together shall equally expand and contract by rise and fall of temperature. The clay found to fabricate wares best adapted to answer, is compounded of best flint ware 75 (entirely free from calcareous particles, which would render the others fusible), and 25 of baked shards in the state of impalpable powder. In some articles the clay has from 5 to 10 per cent. sulphate of barytes, and proportionately less flint.

FRITTED JASPER BODIES.—Frit twenty-four hours, grauen 40, 50, 35, 40; sulphate of lime 30, 50, 26, 40; Cullet 24, 24, 12, 12; flint 10, 16, 8, 8. Grind twelve hours for *Body*, frit 32, 50, 32, 40; china clay 18, 37, 30, 30; blue clay 18, 13, 10, 6; sulphate of barytes 32, 32, 30, 34.

FRITTED PEARL BODIES.—Frit twenty-four hours, cullet 76, 62, 80, 70; minium (red lead) 22, 20, 20, 24; borax 2, 4, 0, 0; nitre 0, 8, 0, 6; flint 0, 6, 0, 0. Grind these severally twenty hours for *Bodies*—frit 12, 16, 12, 30, 16; grauen 50, 46, 60, 20, 54; blue clay 38, 24, 28, 50, 30.

FRITTED DRAB BODIES.—1. Calcine manganese, and pick and pulverise it. Frit four hours equal weights of manganese calc and nitre; when cool, grind and evaporate to the specific gravity of best earthenware slip; and in 92 or 96 of the slip, mix 8 or 4 of the ground frit, blunge well together, and evaporate to the consistence proper for the workman. 2. Calcine nickel, also manganese, which carefully pick and pulverise; then mix equal weights of the two calcs with like weights of good ochre, yellow oxide of iron, and American bole. Of this compound 12 to 6 parts mix with 88 to 94 parts of flint ware body, No. 3, in soft water, and when properly evaporated, the fabricated ware baked in the different rings will have shades, varied from *drab* to *sage*.

RAW BODIES.	CHEMICALS				STONE				JASPER				PEARL			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Kaolin	40	30	...	...	50	...	...	30	18	...	32	...	30	...	...	40
Grauen	...	...	40	36	...	40	46	...	...	33	...	28	...	60	54	...
China clay	30	30	20	24	25	10	12	16	17	17	30	14	32	22	36	12
Blue clay	30	40	25	25	25	30	24	54	30	17	28	18	14	14	4	44
Flint	...	...	15	15	...	15	12	...	...	6	...	12	10	...	...	...
									Carb.	Barytes						
Cullet	...	...	...	...	...	5	6	...	35	27	10	28	14	6	4	4

RAW BODIES.	MORTAR				DRAB				BROWN				FAWN			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Grauen	48	33	40	28	45	40	40	40	...	...	10	6	15	5	...	...
China clay	24	20	20	...	6	12	20	...	6	13	...	...	10	...	10	10
Ball clay	24	25	25	54	27	24	20	16	44	40	20	10	30	30	15	7
Flint	2	11	10	8	...	...	...	...	8	10	12	20	5	10	5	8
Marle (Red)	2	11	5	10	20	20	16	40	40	35	55	60	50	55	70	75
Manganese	...	...	...	...	...	4	4	4	2	2	3	4	...	...	...	...

Raw Bodies.	Cane				Red Por.				Egyptian Black							
	1	2	3	4	1	2	3	4	1	2	3	4	5	6	7	8
Ball clay	18	16	24	20	40	40	10	20	46	53	50	37	40	50	48	44
Marle (Black)	60	55	66	70	25	30	40	40	14	12	8	10	15	14	12	16
Manganese	...	...	...	...	...	...	...	...	8	2	3	3	5	5	6	6
Calcined ochre	4	3	2	...	...	...	...	...	30	33	36	40	40	25	24	30
Brick clay	18	26	8	10	35	30	50	40	2	...	3	10	...	6	10	4

The more carefully the slips are prepared and lawned, the more will improve the fine grain and general appearance of these several wares; while a very useful lesson is supplied in the varied behaviour of the silicic acid to the substances with which it is brought into contact by raised temperature. The best *mortar* and *stone* will be found dense, compact, vitreous in fracture, durable (but not translucent) as porcelain, with indifference to the action of acid or alkali when baked in the first ring of biscuit-oven. I am of opinion that there is a chemical cause for the absence of glaze from jasper and pearl; the high temperature of the baking process would render the acid—phosphoric, boracic, or arsenic—present with some component of the glaze combinative with the heated sulphuric acid which evolves from the sulphate of barytes, to which no glaze yet formed remains indifferent. The marle for the porous ware cannot be *spoiled* by weathering; it is passed through a 14 lawn, and mixed with the others passed through a 16 lawn, and the ware is baked at the top of the gloss-oven. The manganese should be free from calcareous particles, that the tea-pots may not crack by the sudden change of temperature on using them. There appeared a necessity, not to say utility, for adopting the *centessimal* proportions, as greater

accuracy is thereby ensured, even in very large quantities. Any additions to the stated proportions will alter the results much beyond what might be conjectured. Injurious results may ensue from using flint ground with chert having present an extra proportion of carbonate of lime; the small portion abraded rendering the biscuit more vitrescent, ovens full of such ware have sunk down at the usual temperature ere the cause was discovered. The tint will be more or less vivid, as the dry bodies are baked in the first, second, or third ring of the biscuit-oven.

EARTHEN WARE.

Flint Ware.—Queen's Ware. The best kind in biscuit is fine but opaque; in texture and grain coarser than porcelain, fracture porous like common lump-sugar, not vitreous nor translucent, moderately dense, sonorous when struck, hard, firm, and durable; and it is covered with a rich glaze, fine, clear, vitreous, free from specks, transparent to show the embellishments of the biscuit, and scarcely affected by acids, alkalies, or sudden alternations of temperature.*

* There will be few of my readers disposed to believe, that when the subjoined eulogy on Staffordshire flint ware was written, of the twenty Manufacturers who supplied the demand mentioned, it was the intention of Faujas de St. Fond to apply solely to Wedgwood, to whose ware it has been restricted by the partiality of friendship. "Its excellent workmanship, its solidity, the advantage it possesses of sustaining the action of fire, its fine glaze impenetrable to acids, the beauty and convenience of its form, and the cheapness of its price, have given rise to a commerce so active

Queen's Ware and Cream-Colour Bodies :—

	1	2	3	4	5	6	7	8	9	10	11	12
Flint	16	20	18	17	24	20	20	22	24	25	20	25
China clay	16	24	10	17	...	...	16	18	14	18	16	16
Blue clay	24	30	30	50	36	30	25	30	24	20	30	28
Black clay	16	12	16	...	16	20	10	14	12	20	16	12
Brown clay	14	4	12	8	4	8	10	...	12	9	...	7
Cracking clay	6	...	8	...	10	10	9	6	6	...	8	...
Shavings	8	10	6	8	10	12	10	10	8	8	10	12

Blue and Fancy Printed Bodies :—

	1	2	3	4	5	6	7	8	9	10	11	12
Grauen	15	10	6	4	8	6	8	8	6	6	10	12
Flint	15	16	20	24	18	20	25	20	24	18	20	24
China clay	14	12	15	12	18	14	15	14	18	20	15	18
Shavings	8	10	6	8	10	8	12	6	8	11	8	10
Blue clay	20	25	28	26	32	22	28	33	30	45	40	36
Black clay	18	17	15	10	4	16	10	9	4	...	...	...
Brown clay	5	...	10	...	10	4	2	10	5	...	7	...
Cracking clay	5	10	...	16	...	10	...	...	5	...	...	...

and so universal, that in travelling from Paris to Petersburgh, from Amsterdam to the farthest part of Sweden, and from Dunkirk to the extremity of the south of France, one is served at every inn upon *English Ware*. Spain, Portugal, and Italy are supplied with it, and vessels are loaded with it for the East Indies, the West Indies, and the continent of America."

How different is the opinion of Guyton Morveau : "The flint and pipe-clay (or Queen's Ware) is in biscuit more solid than Delft, as being composed of better clays and earth, of flints calcined and in comminution, and previously baked before applying the glaze (more fusible than that of Delft), a real glass, not enduring equal heat, but subject to crack, easily scratches, and into these oily matters penetrate, spot the biscuit, and when the lead is in excess, as it often is, oils and vegetable acids decompose it, and danger attends its use. Very seldom will this ware completely resist the edge of a knife, and after this, it fails before the test of boiling acetic acid, or the yolk of egg boiled hard."

Dipped & Mocha.	1	2	3	4	5	6	1	2	3	4	5	6	Chalky.
Grauen	...	...	...	...	...	...	4	4	6	4	4	6	
Flint	30	25	30	28	25	28	20	26	32	30	28	34	
China clay	20	18	22	20	18	20	24	20	26	18	24	20	
Blue clay	24	30	26	32	30	40	24	20	16	28	20	30	
Brown clay	6	10	2	6	17	...	12	10	...	10	14	...	
Black clay	10	7	10	4	...	2	...	10	10	...	...	...	
Shavings	10	10	10	10	10	10	6	...	...	...	...	...	
							10	10	10	10	10	10	

Seggar Body—Grey marl 50, black marl 25, ground seggars 25. Altered a little for the gloss oven.

For Rings and Stilts.			Pegs.		Saucer Moulds.
Bone earth	—	25	—	C. clay	12
Black clay	84	37	92		28
Grauen	—	25	—		—
Flint	16	5	8		60
Plaster	—	8	—		—

Pass through a 6 lawn.

For Figures on Jasper.

Bone earth	18	22
Flint	6	10
Carbonate of Barytes	38	30
Blue clay	38	38

The advantage of good water for the purpose of blunging is generally admitted; yet I have not known any instance of distilled water having been tried. Although there is no probability of an adequate supply, there could be no impropriety in collecting and using what may be obtained from the steam-engines.

Of the incertitude in *mixing* the clays, up to a very recent date, I shall exhibit four proofs (omitting, from respect to private worth, the names of the

Manufacturers) copied from a Book of Recipes, without owner's name, found on Fenton Park Hill, in May, 1832 :—

6 Barrowfuls of Brick clay.
4 Ditto Blue.
2 Ditto Cracking.
8 of the above in slip.
4 Cornwall clay.
7 Flint. 1½ Cornwall stone.

3 Barrowfuls Black clay.
2 Ditto Brown.
2 Ditto Blue.
40 lbs. Cornish stone.

Of this slip 6 or 6½ to 1 Flint twice through the lawns.

Clay slip	24 oz. to pint.	
Flint	30	do.
Cor. Stone	24	do.

In Slip-tub Ball clay.
11½ inch. Ball clay. 20 Blue.
4⅝ do. China clay. 5 Black.
3⅛ do. Flint 2½ Brown.
24 Quarts Cornish stone.

Or, these two :—

28 inch. Ball clay. 300 gals. Slip.
7 Flint. 70 Flint.
2½ China clay. 20 C. clay.
¼ Cor. stone. 30 C. stone.

And may be used,

3¾	inches in slip-tub.
1	do.
¼	do.

54 of Clay slip.
18 China clay ; or,
16 Flint.

16 pailfuls of Blue clay 24 oz. to pint.
4 do. China clay 24 do.
4 do. Flint 31 do.

Now, as the clay slip may be 27, flint 32, and stone 33 ounces per pint, and this may not be known or corrected by the slip maker, needs there be any surprise, that from directions thus indefinite considerable losses have frequently been experienced, although every care in the manipulations has been taken to cause close integration, toughness, and expulsion of air-bubbles, by often wedging and slapping the clay.

Because of the great difference of circumstances which influence the peculiar properties of wares, in the present state of knowledge no certain method, independent of synthetical experiment, can be devised for their improvement; but in scarcely any instance will the labour of trials fail to be amply repaid by the certainty with which they suggest the best methods; and more especially will this ensue on discovering that all defects in excellence are consequent on those in the adapted proportions of the components. Hence, adding the study of the theory to that of the practice is the most interesting and useful method by which the intelligence of the former can elucidate the experience of the latter. The man intimately acquainted with the manipulations of an Art, with more ease and advantage acquires further knowledge, derives additional information from the suggestions of science, than he who is without either practice or habit in the processes; to whom, whatever is mentioned, can refer merely to things in the abstract; the principles stated being applicable to subjects of which he is devoid of ideas, either assume a wrong direction or soon are forgotten. But the other causes all the rays of light supplied to bear on his own experience; his practice, his own observations confirm and corroborate the information and suggestions received; while with every department of theory, his productions in one way or other identify themselves.

CHAPTER IV.

GLAZES.

PROBABLY the mere inspection of an article of pottery in the state of biscuit would suggest that it is a porous compound, as would be demonstrated by immersing it in water; and as such, by recipience and retention of liquids, decomposable, destructive of its cohesive properties, and therefore inconvenient for the useful purposes of domestic life. This defect originates the application of a coating, varnish, or GLAZE; and the perfection of the Art aims, while aiding the durability of the ware, to improve its general appearance.

Problem.—It is required to form a vitrifiable compound, as a GLAZE or coating of ware, either opaque or translucent, which when baked shall be transparent for printed, or semi-opaque for enamel, yet neither injure, nor be injured by any colours with which it may be in contact.

The glaze being formed by raised temperature exciting simultaneously the momenta of the combinative potencies of the respective components, in the correlative states of agent and recipient, the *plus* and *minus* of the excitement, the more fusible

components must ever be carefully proportioned to the others, that the chemical combination of the whole may be promoted, while the expansion of the orbital spaces of the minute particles may produce and secure the requisite transparency.

This vitrification of heterogeneous substances for the Arts is producing a fresh compound, homogeneous, varying as elastic and transparent, and whose fragments exhibit the vitreous fracture. It results from rise of temperature increasing the momenta of the combinative potencies of the components fusible *per se*, because of their natural dose of alkali, which yet at that temperature would not alone affect or be affected by other substances present, though all soften together. Whether the method of preparing vitreous colours, or of making glass, did or did not suggest a similar formation of glazes, I cannot assert; but the practice obtains preference for all best wares.

Fritting (another term for vitrification) is subjecting certain components of a glaze to a slow rise of temperature, affecting whatever acid and alkali may be present, dissipating all their moisture, water of crystallisation, and carbonic acid gas, then continuing the raised temperature till all carbonaceous ingredients are decomposed without any mineral being volatilised, thereby preparing the results for ready suspension in water in the dipping tub, and precluding the liability to intumesce during the process of glaze baking.

A frit is not necessarily and always a simple agent; the mixture of which it is formed usually has present different combinations, and the components

employed do not act immediately, but by the resulting combinations. The chief component may be one that varies its combinative potency, according to its actual condition, and also the circumstances of the combination, and the reciprocal potencies of the substances in contact.

When such is the condition of the frit, whether the process be continued, according to the components present, 6, 12, 20, or 30 hours, and however much reduced may be the bulk of the components, and also the levity of the mass, through the whole, from the surface to the bottom, will be successive strata, each of which has some of the components less intimately mixed than the others, and is of a density intermediate between the stratum above and that below, instead of the whole being uniform.

The beautiful dense transparence of the frit being in proportion to its duration of the tranquil state while at the raised temperature, it commences, without always completing the chemical union of the silica, alkali, and oxide present; and an opinion is current, that afterwards, while attaining the temperature of the atmosphere, the fluxes fall, the components assume the order of their specific gravities, and render long grinding indispensable.

The exorbitant price of the felspars (fifteen guineas for the petuntse, and half that sum for the kaolin), also probably the deficient supply because of a dispute among the members of the mining company, threw the Manufacturers on their own resources; and the preparation of *substitutes* for these felspars was the commencement of a grand chemical lesson, the compounding of *alkaline glazes*. Doubtless some of these were in the proportions stated in the

published analysis of felspar; but, either from some imperfection in these, as they are not in accordance with the multiples of the combinative potencies of the components, or oversight, and of consequent disregard of some important component, there is remarkable difference. The felspars analysed may be those of granite, which have silica, alumine, alkali, lime and iron present, and the alkali being regarded as *potash*, though now proved to be *lithia*; that failures in the attempts to imitate Nature have occurred, needs not be a matter of surprise.

Whenever the components of alkaline glazes are not in equivalent proportions, they are comparatively less useful, have less combinative potency, and are more easily affected and deranged by other substances as the series of components increases.

Alkaline, or *Fritted Glazes*, whether formed of natural or artificial felspar, are becoming more general, because of these useful and excellent properties: the additional doses of alkali present cause the components to flow together at a temperature lower than would fuse some of them if alone, and than will fuse the raw glazes; to promote the fusibility of the surface with which they first come into mere contact; to be better adapted for chemical combination, and flow free, even, and thin on the ware; by baking formed into a beautiful coating of perfect glass, which will accord so readily with the pyrometric expansibility of the biscuit surface as seldom or never to *craze*.

The ratios of the specific gravities of lead and alkaline glazes as 11 to 2. Even was the consistence of both the same, the latter is cheaper, because a less weight will answer the designed purpose. But to

obtain a like result, the former is required to be twice as thick as the latter. By different dippers the fact has been noticed that like weights of the glazes covered plates in the proportion of 1 to 5; therefore, if their excellence were equal, and their expense as 1 to 5, the alkaline is the cheaper, because of its greater quantity, without taking into the account the diminished expense in baking.

This most regretted defect of the Manufacture, *crazing*, the failure of the glaze, by innumerable peculiar crystallisations with cleavages in various directions, whatever be the cause in the censures consequent, implicates all the Manufacturers and injures them—nationally, as competing with those of China and Europe, and locally, by inducing a character of excellence in favour of the wares fabricated in other places in Britain.

The glaze-baking process may not have raised and a sufficient time continued the ware at a suitable temperature; and before the glaze has been cool it may have been exposed to the sudden action of the atmosphere. When ware thus defective is used for domestic purposes, as bowls for soups, dishes for meat pies, and similar uses, we find the absorbent potency of alumine for oils, animal and vegetable, during raised temperature, almost equal to that for water (page 233), independent of the decomposition of materials, particularly renders obvious the failure of the glaze or *crazing*.

That it is consequent on the incompatibility of the compounds—the components being unequal in fusibility, or imperfectly combining with those of the body during baking—or fresh compounds resulting from the process, we assume from the fact, that it

never occurs when the components are properly adapted for the purpose, and to those of the body; and agreeably to their combinative potencies are mixed by proper manipulations. The particles, solicited in opposite directions, with natural tendency to preserve the respective dimensions of their orbital spaces, and yet by reciprocal combinative potencies solicited to remain in contact, only by the simultaneous expansibility of the orbital spaces as far as may be required by the pyrometric expansion of the biscuit, can have their continuity on the surface preserved. Whatever prevents or separates any portion of this, by affecting the equilibrium of this simultaneous expansibility of all the particles, instead of equalising the potencies of the components, destroys the continuity of the whole. The susceptibility of crystalline substances to resume that arrangement of particles on every favourable opportunity, instructs us to supersede this, and consequent *crazing*, in the compounding of glazes:—

Pulverise a quartz crystal very fine, and mix the powder in a watery solution of borax, into which fluid dip biscuit pot shards, and any thick portion will resume the crystal figures.

The glaze components must quickly separate from the water, as this is appropriated by the biscuit, with whose components and pyrometrical expansibility they must have some chemical reciprocity, and speedily dry into a thin covering of all the surface, with which they must readily incorporate by fusion during the baking, and form a perfect and durable glass, improving the appearance while promoting the durability of the ware, which otherwise would be liable to craze.

HARD PORCELAIN FRITTED GLAZES: Frit 24 hours, pick and pulverise,

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Petuntse	66	75	65	56	60	70	60	60	52	80	67	58	56	64	72
Carb. Barytes	10	12	14	12	10	7	10	10	12	10	12	10	8	14	10
Carb. Lime	4	3	8	9	8	10	6	6	6	4	6	8	6	6	5
Borax	...	10	...	...	16	...	30	24	30	6	...	...	...	10	5
Boracic acid	14	...	10	15	...	10	...	...	...	...	10	29	20	...	...
Soda	6	...	3	8	...	3	...	...	...	...	5	4	8	...	...
Nitre	...	...	...	...	6	...	...	...	...	...	...	...	2	6	8

With 100 parts of each grind, respectively for use, 25 carbonate or white lead, for 1 to 5, and 10 to 15; from 6 to 9, borax instead of lead, for the four *fritted* bodies.*

SOFT PORCELAIN FRITTED GLAZES: Frit 24 hours, pick and pulverise,

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Grauen	44	31	24	17	13	20	...	...	...	...	...	26	25	28	25
Flint	18	10	6	...	...	10	...	...	...	...	...	14	25	20	20
Cullet	30	38	48	70	73	40	69	70	75	68	76	...	...	...	...
Minium	...	...	...	...	10	14	...	...	15	26	14	40	...	48	...
Litharge	...	...	...	...	...	...	18	22	...	...	...	...	40	...	45
Borax	4	20	20	4	...	...	...	...	...	...	...	16	10	...	6
Nitre	4	1	2	9	4	6	8	4	7	2	6	4	...	4	4
Arsenic	...	...	...	...	...	...	4	4	3	4	4	2	...	...	...

* "Among the results of the synthetical essays in my laboratory, at the Imperial Polytechnic School, I obtained a glass perfectly similar to that afforded me by the felspar of Baveno, by urging to fusion, in a platinum crucible, a mixture of 62 silica, 16 alumine, 10 lime and 12 potash."—GUYTON MORVEAU. This most excellent *lesson* has been before the public almost 40 years, yet I cannot find any instance of its having been studied. When it was first noticed by myself, I was equally surprised and gratified by its close accordance with the principle for which I was seeking examples as supporters.

With 100 parts of the first 6, grind 20 or 25 of white lead; with the next 5, grind grauen 10, white lead 15; with others, grauen 15, litharge 10. With 50 parts each of 3 and 5, also of 8 and 10, and 7 and 11, grind for the four fritted bodies grauen 20, borax 15, or 25 and 15, 30 and 15, 27 and 18.

The following are in the precise form communicated :—

	John Riley.			*Joseph Marsh.*		
Frit Cullet.....	16	22	...	16	52	
Red lead...	5	5	...	1	14	Litharge.
Arsenic ...	1	1	...	1	3	
Salt.....	1	...	...	...	...	
Nitre.....	1	1	...	1	6	
Grind with :—						
White lead	25	22	...	24	93	
C. Stone...	14	12	...	14	45	
Flint.....	6	5	...	6	25	
Frit	6	9	...	8	19	

Flow with equal weight of salt, soda and potash.

	George Dean.			*Sampson Daniel.*	
Cullet.....	27	18	.....	16	18
Red lead.....	15	7	.....	34	16
Cornwall stone	13	8	.....	30	8
Flint.....	11	16	.....	25	38
Borax.....	12	10	.....	28	23
Soda.....	5	2	.....	10	5
Tin ash	2	1	.....	4	4
B. Calc.....	1	1	.....	1	1
Frit 75, White lead 25				Frit 60, White lead 40.	

Hard * and Soft † Porcelain Raw Glazes :—

	* 1	* 2	† 3	† 4	* 5	† 6	* 7	† 8	† 9	† 10	† 11	* 12	* 13	† 14	* 15	† 16
Petuntse	70	60	...	...	65	...	65	...	...	...	...	60	35	...	65	...
Grauen	...	...	30	35	...	20	...	30	40	45	30	...	...	32	...	28
Carb. Barytes	6	12	...	...	14	...	10	...	...	...	...	8	12	...	6	...
Carb. Lime	4	4	2	2	5	1	3	3	4	2	2	4	5	2	3	2
Flint	...	...	8	10	...	6	...	8	12	6	7	...	...	9	...	6
Cullet	...	...	12	18	...	12	...	12	23	10	20	...	...	18	...	10
Litharge	...	...	31	10	...	47	...	36	...	25	25	...	...	20	...	37
Borax	20	22	...	...	...	...	21	...	...	...	...	...	...	...	25	...
Nitre	...	2	...	...	3	...	1	...	3	...	2	3	4	...	1	...
Boracic acid	...	...	5	7	3	4	...	3	4	3	4	7	12	5	...	5
Soda	...	...	12	18	10	10	...	8	14	9	10	18	32	14	...	12

Cream-Colour Raw Glazes :—

	1	2	3	4	5	6	7	8	9	10	11	12
Grauen	23	20	25	30	26	27	32	26	22	36	34	40
Flint	12	15	10	14	8	10	20	10	8	8	16	10
Cullet	17	25	15	...	16	15	...	12	10	10	...	...
White lead	48	40	50	56	50	48	48	52	60	46	50	50

Blue Printed Raw Glazes :—

	1	2	3	4	5	6	7	8	9	10	11	12
Grauen	25	35	20	25	30	40	45	30	32	40	40	28
Carb. Lime	3	4	3	3	5	6	4	3	3	5	6	4
Flint	10	12	10	12	15	18	12	20	18	20	25	16
Litharge	46	...	...	38	30	...	21	...	27	...	...	...
White lead	...	36	49	...	...	14	...	25	...	15	13	30
Boracic acid	...	...	...	6	...	6	...	6	...	...	...	6
Soda	...	...	...	16	...	16	...	16	...	...	...	16
Borax	16	13	18	...	20	...	18	...	20	20	16	...

FRITTED GLAZES.—Frit 24 hours, pick and pulverise. If the frit be in seggars, let them be lined with dry flint 33, and Lynn sand 67 parts, by which much loss in picking will be prevented.

1. *Frit*, cullet 70, litharge 18, nitre 8,* arsenic 3, zaffre 1. For *glaze*, grind together; for *printed*, frit 12, grauen 26, flint 12, and in glaze mill mix with white lead 50; for *enamel*, frit 6, grauen 24, flint 16, and in glaze mill mix with litharge 54; for *brown line* (*chalky*), frit 6, grauen 30, flint 8, cullet 4, borax 2, and in glaze mill mix with white lead 50; for *dipped* and *mocha*, frit 15, grauen 25, flint 10, and in glaze mill mix with litharge 50.

2. *Frit*, cullet 70, litharge 22, nitre 4, arsenic 4, zaffre 1. For *glaze*, grind together; for *printed*, frit 24, grauen 40, flint 36, and mix equal weights of the ground glaze components and litharge; for *coloured*, frit 32, grauen 48, flint 20, and mix equal weights of glaze and white lead; for *dipped* and *mocha*, frit 26, grauen 52, flint 22, and mix equal weights of glaze and litharge; for *cream-coloured*, frit 36, cullet 48, common glass 16, and mix equal weights of glaze and white lead.

3. Frit, separate, cullet 80, red lead 12, nitre 4, salt 4; also flint 87 and borax 13; mix equal quantities of these frits, and grind; then for *glaze*, for *printed*, mix frit 36, grauen 30, white lead 34; for *enamel*, mix frit 28, grauen 34, white lead 38.

4. Frit, grauen 36, cullet 32, flint 12, borax 12, nitre 8; grind together for *printed*, frit 60, flint 10, white lead 30. The like mixture of flint and lead with

5. Frit, grauen 18, cullet 10, flint 30, potash 12, bone-earth 15, and Lynn sand 15.

6. Frit, grauen 34, flint 18, borax 25, red lead 18, tin-ash † 5;

* The *Nitre* is useful by promoting the high heat to readily fuse the whole mass; for, combined with potass, the nitric acid sustains a higher heat than with any other base; and, by its generating carbonic acid gas, improves the colour of the glaze.

† The *Oxide of Tin* may be prepared for glazes by the following processes: melt block-tin and keep just melted until the whole is converted into a grey powder. (If the heat be too great, the colour will be straw-yellow.) The usual oxide is prepared by (*a*) dropping into cold water the tin melted in a ladle; (*b*) the fine lamina of metal are placed on a flinted dish, between two layers of nitre in powder, and calcined; the powder is removed, and the remaining metal similarly treated. Or, the *oxide purchased* often is adulterated with lead,

grind together frit 75, grauen 10, flint 15; and mix glaze 60, white lead 40, for *printed;* and glaze 70, litharge 30, for *enamel.*

7. Frit, grauen 36, flint 17, borax 20, red lead 24, tin-ash 3; grind together frit 16, grauen 46, cullet 18, flint 20; mix glaze 54, and white lead 46.

8. Frit, separate, cullet 65, red lead 25, nitre 5, arsenic 4, zaffre 1; also flint 50, red lead 20, nitre 6, borax 24. Mix equal weights of these frits; then grind together frit 44, cullet 56. Grind together for *printed* glaze, frit 40 parts, grauen 25, white lead 25, flint 7, nitre 3; and for *enamel*, substitute litharge 28, without nitre; and for *flat*, glaze 45, white lead 45, borax 10.

9. Frit, grauen 42, flint 10, red lead 25, borax 22, zaffre 1; grind frit 73, grauen 18, flint 9; then mix, for *printed*, glaze 63, white lead 37; or, for *enamel*, glaze 67, litharge 33; or, for *mocha*, glaze 55, litharge 45.

10. Frit, cullet 68, red lead 20, arsenic 5, nitre 6, zaffre 1; grind, and for *printed* glaze, frit 80, white lead 20.

11. For *flat*, frit flint 50, red lead 16, borax 25, nitre 8, zaffre 1; grind, for *printed*, mix frit 75, white lead 25.

12. Frit, separate, cullet 90, white lead 9, zaffre 1; also cullet 68, red lead 27, arsenic 5. Grind 20 parts of 1 with 80 of 2; or 25 with 75 for *flat*. Of mixed frit, grind 30 with grauen 50, flint 20; then mix glaze 54, lead 46.

13, 14. Frit, cullet 60, 57, red lead 15, 18, arsenic 10, borax 15, 10, nitre 0, 5. Grind together frit 20, 40, cullet 60, 0, stone 15, 48, flint 5, 12; then mix glaze 75, 50, white lead 25, 50, for *printed;* and for *mocha*, glaze 70, 60, litharge 30, 40.

hence is improper for *glazes*, though useful for *enamels*. The usual *tin-ashes* are thus formed: Count Chaptal first suggested their use fritted with silica 1, ashes 2. In an open utensil heat to a low red, lead 100, tin 25, or 30, or lead 100, tin 110, and skim quickly till no more be formed, and preserve any residue; then the skum (or oxide) reheat till no longer inflammable, and the whole is of a grey colour. For oxide of tin may be substituted with advantage the very fine powder of calcined *native phosphate of lime* (or, in its absence, the earth of bone, carefully picked before being ground, and then calcined), being invitrescible, and very white.

The following are in the precise form communicated :—

William Moore.

Fritted.

Frit—Cullet.....	20 lb.	Grind with White Lead....	52
White Lead	2	C. Stone.....	28
Common Salt	1	Frit	12
Arsenic.....	¼	Flint.....	15
Blue Calc ...	¼ oz.	Borax.....	6

Without Frit.

Grind together—		Add—	
White Lead	56	B. Calc.....	1 oz.
Cornwall Stone.....	28	Flow with Potash	8
Flint.....	14	or	
Cullet.....	12	Salt Rock	4

John Barlow.

Frit separately—				Grind together with—	
Cullet.....	34	Flint....	30	W. Lead....	113 lb.
W. Lead....	4	Borax...	6	C. Stone....	53
Com. Salt...	2	Soda....	3	Stain.....	5*
Nitre.....	1				

* W. lead 4, nitre 1, salt 2, cullet 60, borax 2, B. calc 20.

John Clowes.

	Frit separately—					
	(1)	(2)		(1)	(2)	
Cullet.....	44	32	.....	4	4	Borax.
Red Lead.....	4	4	.....	24	18	Flint.
Nitre.....	1	1	.....	—	1	Soda.
Salt.....	2	1	.....	1	2 oz.	B. Calc.

Grind (1) together with			(2)
White Lead.....	117	.....	156
Cornwall Stone.....	57	.....	72
Cullet.....	25	.....	36
Borax.....	6	.....	12

The preceding are immediately in dates prior to the two following, which are employed more generally than any previously compounded ; and by their introduction, the different tints of beautiful colours have become useful, with which no other glaze could be with confidence employed. The employment of lime with boracic acid and soda, and borax, accomplishes the vast difference.

	(1)		(2)	Glaze.
Frit—Grauen	100	or	120	100 lbs. of Frit 1, grind with
Borax (or	60		80	25 White lead ; and of No. 2
Tincal	80)		(100)	with 30 White lead.
Flint	50		50	
Soda	20		...	
Whiting* ...	20		25	

* These salts are incompatible with each other, and will combine in only extremely minute proportions in water at the regular temperature ; consequently, whenever any of them results from the components of the glaze, there is every reason to fear *crazing*.

Salt.	*Incompatible with*
Muriate of Barytes	Carbonated alkalies, earthy carbonates, and sulphates.
Sulphate of Lime	Alkalies, carbonate of magnesia, and muriate of barytes.
Nitrate of Lime	Carbonated alkalies, carbonate of magnesia, and of alumine, sulphates (except of lime).
Muriate of Lime	Carbonated alkalies, earthy carbonates, and sulphates (except of lime).
Sulphate of Magnesia	Alkalies, muriate of barytes, nitrate and muriate of lime.
Muriate of Magnesia	Carbonated and sulphated alkalies.
Alum (Potash—Sulphate of Alumine)	Alkalies, muriate of barytes, nitrate and muriate of lime, carbonate of lime, and of magnesia.
Sulphate of Iron	Alkalies, muriate of barytes, and earthy carbonates.
Fixed Sulpd. Alkalies	Nitrate and muriate of lime and of magnesia.

ANALYSIS OF FRIT.

We assume that the frit has *lead, silica, alkali,* and *colorific oxides* present, which we wish to determine. *a.* Of the frit, whether glaze or colour, in fine powder, take 10 grains, and in aqua regia (2 N A and 1 M A), 50 grains, carefully boil about 80 minutes; add ten bulks of boiling pure water, filter, wash with warm water, dry the filter; and its contents with thrice the weight of caustic potass, fuse in a porcelain or silver (not platinum) crucible; when cool, pulverise and dissolve in muriatic acid, add much pure water, and slowly evaporate dry. The residuum again dissolve in muriatic acid, and add plenty of water; repose 24 hours, and then filter out, wash well, incandesce, and weigh the silica precipitated. *b.* The filtered liquid slowly evaporate dry, again add plenty of pure water, mix well, and after 48 hours' repose, filter out and treat, as just directed, the remaining silica. *c.* The liquid left from the filter alkalinise with ammonia till no more be appropriated; repose 24 hours, then filter out and wash well the oxides precipitated, and lay aside for process *f.* *d.* To the liquid from the last filtering add the solution of oxalic acid till aciduline; allow 12 hours for repose, then filter out, incandesce, and weigh the lime obtained. *e.* Next acidulate the liquid with muriatic acid, and by slow evaporation obtain the muriate of soda. *f.* In muriatic acid boil the precipitate, *c*, 80 minutes, add plenty of warm water, and by the proper tests determine which oxides are present, and then obtain them by the usual methods. (See pages 115-119.)

ANALYSIS OF GLAZE.

We may suppose that the glaze has present *lead, soda, lime, boracic acid, alumine and silica.* *a.* In muriatic acid separate the substance, and when all is appropriated by the acid, raise the temperature to 140 Fahrenheit, and continue till all the liquid is evaporated; next moisten the residuum with concentrated muriatic acid, add fifteen bulks of distilled water; allow to repose 24 hours, decant off the liquid, and throw on a filter the *silica* deposited, which wash well, and treat as directed in page 141. *b.* To the filtered liquid add test 2 (caustic ammonia), and after 12 hours' repose, filter out the precipitated *alumine.* *c.* The liquid treat with oxalate of ammonia, raise the temperature, let it repose 12 hours, then filter out the lime. The liquid yet contains lead, boracic acid, soda and sal ammoniac. By processes, 2, *c.* (p. 126), and 2, *b*, (p. 130), determine the presence and quantity, or proportion of the two former, lead and acid; and then, to find the soda, *d*, again completely evaporate the liquid, and keep at a raised temperature till all the sal ammoniac is dissipated, without fusing the soda. Were magnesia present, washing would dissolve the alkali and leave the earth deposited.

To separate any potash, or lithia, or both, when present with the soda: To the salt left (*d*), 6 parts, add 94 of chloro-platinate of sodium, and the potassium, when alone present, will exchange condition with the sodium in the double salt. Add plenty of warm pure water, gently evaporate dry; by alcohol appropriate the chloride of sodium, and the excess of

the chloro-platinate of sodium. The chloro-platinate of potassium wash with alcohol, dry, weigh, and 100 of the salt will have present 30·73 chloride of potassium. The weight must be deducted from that of the saline mixture used, and thereby is determined the quantity of the chloride of sodium. For the lithia, add phosphoric acid, and phosphate of soda in excess; evaporate dry, add plenty of *cold* water, evaporate dry, incandesce and weigh, and 100 of the salt will have present 15·08 lithia. The weight of the chloride will supply the quantity of the alkalies together, and of each separately. When the tests for potash and lithia are indifferent, the presence of soda is inferred.

The following are genuine recipes of the parties whose names they bear :—

John Hancock.

Body.		Frit.		Glaze.	
C. Stone....	140 lbs.	30 lbs.	...	30	Frit—Grind with
China clay .	120	10	Glass	24	White lead
Flint	100	4½	...	36	60 lbs.
Blue Calc 2 or 3 oz. Blue clay		20	Nitre	4 oz.	

Aaron Hancock.

Body.			Glaze.
Cornwall Stone	50	60	Frit—Cornwall Stone 42, Cullet 49,
China clay	10	20	White Enamel 7 (Cullet 16, Red
Blue ditto	30	30	Lead 5, Borax 1, Arsenic 1, fused
Black ditto	20	16	together 6 hours), Pearlash 2, Nitre
Cracking ditto .	20	16	1, Blue Calc 1½ oz.; and this charge
Flint	20	30	grind with 56 lbs. White Lead.

William Whieldon.

Body.

Cornwall Stone.....	200	120
China clay.....	100	80
Blue ditto.....	100	120
Black ditto.....	80	50
Flint.....	150	80
Blue Calc	4 oz.	2 or 3 oz.

Glaze.

Blue Frits.			Grind together—	
Cullet.....	26	23	Frit	100
Litharge.....	7	16 Stone.	White Lead	75
Nitre.....	3	15 Flint.	or	
Arsenic.....	1½	15 Borax.	Frit	120
B. Calc.....	6 oz.	8 oz.	White Lead	95

Flow with 12 oz. Pearlash, and 1 oz. Bay Salt.

Charles Penny.

Body.

Frit	40	—
Bone	160	150
C. Stone	80	100
C. Clay.	80	80
Blue do.	16	20

Glaze.

Frit—		Grind together—	
C. Stone....	40	Frit	80
Soda.....	10	C. Stone.....	30
		Flint	40
		W. Lead.....	65
		Borax.....	20

Stain with Blue Calc.

William Handley.

Body.

Bone.....	170	220
C. Clay....	105	60
Blue ditto.	30	160
Felspar....	95	120
Blue Calc.	4 oz.	6 oz.

Glaze.

Frit—			Grind together—	
C. Stone....	50	30	Frit	80
Cullet.....	60	30	W. Lead	20
Red Lead ..	20	10	or	
Borax.....	50	20	Frit	40
Nitre.....	6	6	W. Lead	40
			Cullet....	20

George Jones.

Body.

Cornwall Stone	120	120
Bone	88	80
C. Clay	56	25
Blue ditto	24	50
Flint	20	16
Blue Calc	4 oz.	4 oz.

Glaze.

Frit—				Grind together—		
Cullet	20	15		Frit	10	30
Red Lead	20	10		Cullet	4	20
Flint	60	20		W. Lead	6	30
Arsenic	1	6	Nitre.	Flint	1	—
Borax	40	10				

The semifluid glaze must have only that consistence or specific weight per ale pint, which will be in precise accordance with supplying a coating to the biscuit agreeably to its pyrometrical expansibility and peculiar components. The *cream-colour glaze* must be opaque, clear, free from specks, much like velvet, and indifferent to the soliciting of acid and alkali, and to alternation of temperature. In *raw glazes*, or those whose components are mixed without previous preparation, there is considerable care needed to prevent, in the dipping-tub, the metallic oxides precipitating, because of their specific gravity; whereby, instead of the useful components remaining suspended, merely an aqueous mixture of earthy components is present, inadequate to supply a suitable proportion of materials to cover the biscuit. Continued agitation does not always avail, and the employment of a *flow* of common salt may produce a yellow tint prejudicial

to the ware; and in the fritted glazes, the use of *spirit of salt*, or muriatic acid, cannot be otherwise than injudicious, and should be superseded (may I ask whether *raised* temperature would not answer?); for when the baking process dissipates the acid, its gas carries away with it whatever it had previously solicited to combination.

Soda, or Barilla-ashes, in the state of carbonate, is the alkali generally used to promote the vitrification of the earths and metallic oxides as silicates, because, by its greater potency in combining with silica, it forms a *thinner* glaze, and is cheaper than potash. For other uses, its sophistication by neutral salts and alkaline earths would depreciate its value; but as these generally promote vitrescence, its utility for potters is scarcely affected. The carbonic acid dissipates in the oven, and all the substances fuse together into a silicious mass, the soda as a pure (not carbonated) alkali combines with the silica, and the glaze is equally with glass durable when cold.*

* The following notices were overlaid when page 220 was printed, else they would have appeared there:—

Natron, native sesquicarbonate of soda, is found at the foot of a mountain in the province of Suckena, a subject-state of Tripoli, from which city it is twenty-eight days' journey, and two from Fezzan, in Africa. It has a varied thickness from an inch to a line, and occurs in crystals formed into prisms, fibrous masses, and congeries of crystals. It has translucence, vitreous glistening lustre, grey or yellowish-white colour, mild alkaline savour, is soluble in water, but indifferent to the action of the air.

Tincal is found in Thibet, China, Ceylon, Tartary, Saxony, Transylvania, and Potosi. That from Thibet is supplied by an extensive lake, fifteen days' journey from Tisoolumbo, the capital of the country. The situation is elevated, and most of the year the

But *Borax* is unrivalled in its property of promoting the fusibility of vitrifiable components, causing the compound to flow most freely, without

springs are frozen, and deposit on the edges and shallows both borate and muriate of soda (tincal and common salt). The deposit leaves holes that are refilled, and again emptied as needed.

A *Nitrate of Soda* (with some impurities of nitre, salt, clay, and sand) has recently been introduced into the market from Tarapaca in Chili. Its properties are not yet determined, but its crystallisation and efflorescence indicate some mode of preparation.

The material named *Lynn Sand* is of a very fine quartzose nature, supplied from the small port Lynn, on the coast of Norfolk, and a similar kind is supplied from Alum Bay, the western extremity of the Isle of Wight. Its use commenced and continues (whether calcined to separate all carbonaceous impurities, or merely washed to remove soluble ingredients), because it is an excellent substitute for flint, saving the expenses attached, and the small portion of alkali which remains assists in its vitrification.

Arsenic is a very powerful flux in promoting complete vitrification, and with this advantage, that whatever carbonaceous particles it may be in contact with, it volatilises likewise with them during the fixation of the oxygen. It is very useful in the dipped ware for aiding the manganese. Nitre also dissipates any carbonaceous ingredients with which it has been in contact previous to fusion.

Lead, even at a low quotation, is dear for glaze, and the only reason for its continued use is the knowledge of its application. It renders the glaze heavy, fusible, soft, and easily injured by acid and alkali when heated. The proportions of the oxides introduced into the frit, as well as mixed with it after grinding, must be so carefully adapted to the whole quantity of components, also to complete intermixture with those which are alkaline, that pernicious results may not ensue from their adoption. The red oxide promotes the vitrification, at a low temperature, of all the components, and increases the density without impairing the lustre of the glaze. Litharge, however, will answer in smaller proportions than red or white lead, as 86 to 116 and 126. It will *per se* fuse into a clear transparent dense glass, remarkably soft and velvety to the touch,

bubbles or specks, and thus increasing the beauty of the glaze. It has not yet been solved how much of the boracic acid is evolved during the glaze-baking, and it needs careful adaptation for colours formed of nitro-muriates. With alumine it slowly forms a permanent glass, opaque with excess of the earth. And as the fineness of tint, from a solution of cobalt, improves by its purity, there seems a proof that in proportion to the excellence of the materials which composed the body will be the beauty of the *Blue Printed Ware*. The transferring process causes a mechanical, and the glaze-baking a chemical combination of the silica, alumine and cobalt.

As a substitute for borax, some employ equal weights of nitre and flowers of sulphur, incandesced, till all sulphurous acid has evolved, when the sulphonitrate of potash is poured upon an iron plate, and when cool, the scum is carefully separated from the chemical compound.

and fusible at a low red heat. When the temperature is very high, unless earths are present, this oxide will permeate and escape through common crucibles almost like liquid through a sieve, and corrode the vessel. In forming a glaze, both red and white lead form litharge, by the high temperature of the baking process dissipating the oxygen of the former, and the carbonic acid of the latter, and their value must have the ratio of their respective numbers for them to be equally cheap.

COLOURED GLAZES, DIPS, AND SMEARS.

THE following are the components of the best in present use :—

COLOURED GLAZES.

Black.—1. Frit together and grind for use, black oxides of copper, manganese, and iron, and oxide of cobalt, equal parts, with 2 parts nitre and 20 cullet. For *inside*, white lead 80, flint 16, manganese 4. 2, 3. In clean water mix manganese 8, 4, ochre 46, 12, blue clay 46, 84 ; pass through the lawn for use.

Ditto. (*Shining.*)—1. To flinted slip (4) 60 parts, add red lead 40 ; of this liquid 86 parts intermix with 14 manganese. 2. White lead 66, manganese 24, flint 10, mix together for use.

Brown.—In slip 3, 33 parts, mix red lead 62 parts and flint 5 (and for *black*, add 2 parts manganese). 2. Glaze 5, 33 parts, and frit glaze 3, 67 parts. 3. For jug necks, use 67 and 33.

Yellow.—1. In cream-colour glaze 4, 72 parts, mix base yellow 14, and litharge 14 parts. 2. Glaze 7, 80 parts, biscuit yellow 20.

Green.—Frit together and grind for use, white lead 54 parts, flint 27, blue clay 9, oxide of copper 9, cobalt calc 2, or 1, or sulphate of copper 60, flint 20, cullet 20 ; grind with litharge 35, flint 27, grauen 16, frit 14. Mix frit 15 parts, glaze 6, 85 parts ; or 40 and 60 for edging. 3. Frit lead 33, copper calc 28, flint 22, cullet 17 ; grind and mix frit 20 parts, printing glaze 4, 80 parts, or for dessert-ware, frit 24, glaze 76 ; or glaze 4, 80 parts, oxide of copper 20.

DIPS.

Brown.—1. Mix best ware shavings into slip 24 oz. to pint, then to slip 80 parts, add ochre 13, manganese 7, and bake in the first ring. 2. Calcine ball clay, brick clay, ochre, and Bradwall red clay, equal parts ; pass through 14 lawn, then to 92 of liquid add 8 of oxide of nickel. 3. (*Mingled.*) Best shavings slip 75, ground per oxide of iron 25. Bake as above (or 4, brick clay 97, zaffre 3, bake in second ring). 4, 5, 6. (*Purple.*) Brown dip 1, 80, 48, Ironstone 20, 5, Manganese 0, 48. 7. Best ware shavings

slip 34, brown dip 56, ochre 8, manganese 2. 8, the last, with ochre 4, Spanish brown 4, for china jugs.

Blue.—1 and 2. Blue clay 28, 23, grauen 50, 27, flint 0, 27, plaster 20, 0, China clay 0, 15, blue calc 2, 8; through 14 lawn.

Grey.—Best shavings slip 94, blue calc 6; or 75, flint 15, emery 6, manganese 4; grind well for use.

Green.—1. Best slip 96, blue calc 3, copper calc 1. 2. Or, (*mingled*) calcine well ball clay 75, blue calc 25; and to 20 of this add 80 best slip. 3. Stone body slip 94, and zaffre 6 parts. 4. Black marle slip 92, blue calc 8. 5. Cane dip 96, blue calc 4. The three last are *dark* and *olive.*

Cane.—Equal quantities of best slip and orange dip.

Orange.—Equal quantities of brown dip and black marle.

Red.—Calcine, and grind for use, brick clay 60, Bradwall do. 40.

SMEARS.

In hot water mix well—salt rock 24, 33, 59, 34, 54, potash 60, 45, 9, 48, 42, nitre 18, 22, 32, 18, 14. And to cream-colour glaze 80, add 20 of the smear, for the seggars; or 86 and 14, 90 and 10.

WASHES.

For Seggars.—In water 2 gallons slake 2 lbs. of quick-lime; to lime-water 5 quarts, add common slip without flint 1 quart; some persons add 10 oz. of salt and 6 of potash.

For glaze-baking the former; or, lime 6, slip 1, cream-colour glaze 6; lead 4, grauen 1; and for bottom, outside, add litharge 5, flint 1.

To prepare Barytes for using in Glaze.

Take a seggar of the size adapted to contain the quantity needed; line this one inch thick with powdered charcoal, put in the sulphate of barytes, cover well with charcoal, put on a hiller (cover), and lute down well with wad clay; place the whole at the top or inside of the mouths of the oven as soon as the *firing up* is completed. At a white heat the sulphuret fuses, and is then to be cast into a strong vessel of boiling-water, which must be drawn off by siphon, and its crystals will be ready for further employment; and the water itself may also be used when cleared of charcoal.

In GRINDING these mixtures for the different compounds, whether bodies, glazes, or colours, an indispensable condition of the active power is the extension of the arms over the radius of the pan, to constantly rake up or agitate the substance immediately after being affected by the runner, that new surfaces may be presented for grinding on each revolution. That portion of the runner nighest the centre describes a circle with least radius, and each portion enlarges the circle in proportion to distance from the centre; yet all parts of the runner describe their respective circles in the same period, thus varying the force of abrasion by the slower or quicker motion of the runner over the paver, which arrangement is requisite to form impalpable powders. In *dry* grinding it constantly undermines, breaks, and causes to deposit whatever portion of the substance may have caked up against the sides of the pan; for when a certain state of comminution is attained, the pressure consolidates the mass and retards abrasion. In *semi-fluid* grinding the like arrangement to disturb the materials that they may not *set* (or technically *suck*) is further aided by the introduction of water in which quick-lime is present; water saturated with common salt; water saturated with equal proportions of sulphates of zinc and iron; dilute solution of sulphuric or muriatic acid. For blue and chrome green, a very useful preventive is a crystal of gypsum (or of barytes), in size determined by the quantity of colour under the process.

GLASSES.

MANY researches of science needing articles of this Manufacture, attention has been given to improve it every way, so that its fabrications, in beauty and refulgence of substance, and in variety, splendour, and elegance of figure, greatly excel those of the countries whence the Art was originally introduced, to increase the conveniences and comforts of life. As cut forms, of varied sizes and facets, thereby we promote the beautiful prismatic combinations with lustres and chandeliers; as plates for mirrors we assist beauty to render available all the elegancies of the toilette, and we review near objects; as vessels, to distinguish, by the transparency, the clear or turbid state of the liquid presented for refreshment; and as sheets, while admitting the solar rays for our enjoyment of the day, yet excluding the pelting storm, the ruthless blast, or the inclement frost.

GLASS, in the scientific application, signifies *all* compounds hard, brittle, vitrified, and often translucent, which result from continued high temperature acting on two or more earths present together, as alumine, barytes, and lime, or silica, barytes, lime, and fluor spar; certain proportions have chemically combined; and yet the compound has not hitherto been rendered sufficiently tractile to be fabricated into articles of utility. Hence, in popular language,

GLASS is the translucent vitrified substance formed by continuing many hours at the temperature of 120° Wedgwood, 16000° Fahrenheit, certain earths and alkali, and metallic oxides; the kinds are FLINT-GLASS (the *crystal* of foreigners), used for the most valuable vessels and ornaments (and *coloured* by certain metallic oxides to imitate natural gems); PLATE-GLASS, for looking-glasses and windows, where appearance and protection are preferred to expense; CROWN-GLASS, or best sheet window-glass, used in most sash-windows, where a tint in the light admitted would be disagreeable to

the vision: BROAD-GLASS, or coarse greenish window-glass, used for common purposes; and BOTTLE-GLASS, coarse common green glass, whose use is well known to almost every person.

The essential components of Glass are *sand* and *alkali*, with the addition of *lime*, *nitre*, *borax*, and *oxides of lead*, *arsenic*, and *manganese*, in some of the kinds.

The earths alone, when pure, likewise the alkalies, do not vitrify; but because of greater capacity for appropriating and concentrating heat, the latter becomes solvents, or fluxes, of those refractory substances, by causing the compound to vitrify. Hence, when these readily fusible, and those refractory substances, are together raised to a very high temperature long continued, certain proportions chemically combine, the adventitious substances are separated, the melted mass assumes the viscidity of molasses, or bird-lime, and from it the artisan takes whatever portion he may require to form the article needed, and which, passing through the lier in annealing, has its temperature gradually reduced to that of the atmosphere.

FLINT-GLASS (so named because at first the silicious component was the powder of calcined flint, quartz, or rock-crystal) is that brilliant, beautiful vitreous transparent compound, fabricated into the finest vessels for the table, and the splendid ornaments of the drawing-room. Some practical men are of opinion that on careful and perfect vitrification of the components depends its excellence, more than on their relative proportions. But wherever loss can be superseded, as in both instances, there is advantage in urging attention to the most minute particulars. The Components are:—

	1	2	3	4	5	6
White Sand * (purified)	52	52	54	56	55	56
Best Pearl Ashes (do.)	16	16	32	32	32	30
Minium	30	—	2	40	—	—
Litharge	—	30	—	—	43	42
Nitre	2	2	2	2	—	2

* On a farm called Holly-heath, near to the railway, Crewe, Cheshire, is a bed of this fine sand, from which all oxide of iron has been abstracted by an adjoining bed of peat. The trials made with it (1837) are very excellent.

The sand is purified by careful washing; the ashes by lixiviation and evaporation of the liquid dry. The lead renders the glass more clear, transparent, refractive, dense, susceptible of very high polish, and indifferent to sudden alternations of temperature, while the additional tenacity adapts it for being easily controlled and fabricated by the artisan. The nitre avails for diminution of lead oxide (whose excess renders the glass very soft), and appropriates any adventitious earths, as well as corrects the tint caused by manganese.

The components are carefully mixed, put into the pot, and raised to the temperature needed for their chemical combination, which is known by neither bubbles, vapours, nor other impurities on the surface, but the mass appears pure, colourless, translucent, and vitrified. The salts indifferent to silica form a white froth, of *glass-gall* or *sandiver*, which is constantly skimmed off, else it would injuriously combine with the earths of the pottery; the temperature next is lowered, till the mass becomes viscid and tenacious, proper for the manipulations.

Coloured Glasses, or Pastes.—*Artificial Precious Stones.* These require to approach, as nigh as possible, those of Nature, in hardness from the components, clearness from speck or bubble, perfect translucence, and lively splendour of colour. To ensure successful results in this branch, most carefully must be regarded constantly the precise degree and continuance of the temperature, the difference by change of alkali, the purity of the components, the preparation and precise state of the metallic oxides, solvent or colorific, and the minute quantity which will communicate the required tint to a determined weight of the white glass.

They are formed by re-melting, after again rendering friable by suddenly cooling in water while incandescent, one of these frits:—

	1	2	3	4	5	6	7	8	9	10	11	12	13	
White Sand (purified)	30	25	25	30	48	35	30	14	17	26	27	55	52	
Minium	—	—	50	—	—	52	60	42	50	63	64	9	6	Bone-
Litharge	48	—	—	—	—	—	—	—	—	—	—	—	—	Ash
Arsenic	4	—	—	—	—	—	—	—	—	—	—	—	—	
Ceruse	—	57	—	—	6	—	—	—	—	—	—	—	—	
Potash (carb.)	—	12	12	18	—	—	—	—	—	—	—	36	7	
Ditto calcined	—	—	—	—	26	3	5	2	1	4	3	—	—	
Borax ditto	9	6	—	52	20	10	—	42	32	7	6	—	7	
Nitre ditto	9	—	13	—	—	·3	5	—	—	—	—	—	28	Opaque

The above White Glasses, treated with 1 to 1·5 per cent. of colorific oxide, readily take any required tint of *purple* and *violet* by oxide of gold, *red* by manganese and by iron (which also supplies tints of *green*, *blue*, and *black*), *hyacinth* by tin, *yellow* by silver, bismuth, and lead, *blue* by cobalt, and *green* by nickel.

Artificial Garnet. Glass (No. 3) 66, Glass of Antimony 33, Purple of Cassius ·5, Oxide of Manganese ·5. Or (best prepared in a platinum or plumbago crucible, because of often permeating porcelain), Powder of Rock-crystal 26, Minium 73, Zaffre ·2, Oxide of Manganese ·8, fritted and re-melted.

Artificial Emerald. Glass (No. 2) 98, oxide of copper 1·8, oxide of iron ·2. Or, Glass (No. 7) 95, copper 4, iron 1. Or, 92, 7, 1.

Artificial Amethyst. Glass (No. 5) 96, Nitre 3, Manganese 1, Purple spice.

Artificial Sapphire. Glass (No. 1) 98, Zaffre 1·8, Manganese ·2. Or Silica 35, Soda 18·5, Minium 45, Zaffre 1, Manganese ·5, fritted and re-melted.

Artificial Opal. Glass (No. 3) 88·4, Bone Ash 8, Muriate of Silver 3, and Magnetic Iron Ore ·6.

Wiegleb recommends for a White Glass, a frit of Silica 31, Alumine 31, Magnesia 31, fluate of lime 7, in place of sand, or powder of flints. Mix frit 50, Ceruse 6, borax 19, purified potash 25, or as Glass No. 5.

Manganese only supplies a red tint to glass, entirely free from impurities and arsenic, and with iron produces a black glass. Its potency in combining with earths corrects the colorific effects of impure materials, during complete vitrification, added in proportion to the strength of the tint. When excess has been used, a strong stick is forced through the melted mass, and supplies carbon; the carbonic acid evolves and produces intumescence, during which the tint disappears, and the glass becomes clear and transparent. The like result ensues on forcing to the bottom and agitating in the mass small lumps of arsenic,

which also promote the combination of the components, the due proportion remains inseparable by any usual processes, and the other volatilises with any carbon present. When a portion remains present, not intimately combined, the glass has a wavy hue, gradually darkens, and decomposition progresses, till the articles entirely fail. In fabricating white glass, for the optician's use, great care must be exercised to prevent strata of different densities and refractiveness being formed by the deposit of the oxides in the pot, which also vitrifies the surface in contact. When carbonate of copper, prepared from the sulphate, or the *æs ustum*, is used with Glass No. 1, a fine *green* is produced; and when the red oxide is used, *carmine* results. Glass No. 5, 96, Copper 1, and Iron 3, supply a deep *red*, and this varies with the altered proportions of the oxides. Both chrome and cobalt are indifferent to temperature, and also to the kind of glass; a *green* resulting from the former, and the latter alone supplies a rich *blue;* with manganese and iron, *black;* and with lead and antimony a beautiful *green*. (*See* CHAP. IV.—COLOURS.)

PLATE-GLASS is now in request, because more durable and discoloured than the crown or sheet-glass—properties of greater value than its increased expense. Its components are :—

	1	2	3	4	5	
White Sand	38	38	43	36	43	
Carbonate of Lime	5	5	—	—	—	
Powder of Quick Lime	—	—	4	3	4	
Soda, purified	17	18	26	24	27	
Cullet (of plates)	39	38	25	36	24	
Manganese	1	1	—	1	1	
Nitre	—	—	2	—	1	
Cobalt (a spice)	—	—	—	—	—	

The sand is the sharp grained which will pass (with the portion almost impalpable) through a fine wire-cloth sieve; the agitation mixes these, and supersedes the inconvenient clotting when only the latter is used; by intimately mixing with the alkali, ready combination by fusion ensues; and also it separates impurities and the coarse sand, whose fusion would require extra time and fuel. The soda is

preferred, because, when moderately pure (prepared by decomposing common salt, or lixiviating and evaporating barilla), it increases the fluidity of the melted mass, which readily is spread over a flat surface; and during the rise of the sandiver, the acids combined are by the high temperature dissipated more readily than when potash is employed.*

The lime ensures brilliance, clearness, durability and solidity, used in the proportion of not less than 4, nor more than 9 per cent., as chalk or powder; the carbonic acid causes intumescence, which must be carefully noticed to preclude losses; and a larger dose than the above combines with and injures the interior surface of the pots, diminishing the permeability of heat proportionately with increased vitrification. When *attention* is duly paid to this, the quality of the limestone will be of minor importance—as of Gibraltar, St. Vincent's near Bristol, Walsall, Dudley, Caldow Low, and Wales. The cullet is prepared by being cast, while incandescent, into cold water. The presence of tint is superseded by the incorporation of the blue of cobalt, the red of manganese, and the light yellow of the soda and silica.

Crown-glass. — This, because without a metallic oxide as a solvent, is harder than flint-glass; and to be fabricated into vessels for like purposes, would require great trouble and patience of the artisan and additional expense of the Manufacturer. The components are:—

	1	2	3	4	5	6	7	8	
White Sand	40	60	37	50	59	60	58	64	
Carbonate of Lime	2	—	—	3	5	1	14	1	Nitre
Powder of Quick Lime	—	3	4	—	—	9	—	8	
Carbonate of Soda	18	—	—	17	—	30	—	27	Sulp. Soda Salt
Cullet, of sheets	40	5	37	30	12	—	—	—	
Pearl Ashes (*purified)	—	32*	22*	—	24	—	28*	—	

About 1 per cent. of charcoal appropriates the sulphuric acid, and precludes not only the loss by intumescence, but

*Yet I am disposed to think that borate of barytes will render equally fluid the silica and potash (as has been asserted of borax), as lime renders the silica and soda.

also the annoying sulphurous odour. In proportion to the moderate purity of the components will be the absence of tint, and the need of their removal by cobalt and manganese. There often is some iron present with the barilla, or kelp, which causes the deleterious tint. When more cullet is used, the compound is less easily controlled by the artisan, because not sufficiently fluid through diminution of alkali. The temperature is kept at a certain degree, as nigh as possible thirty-five to forty hours.

BROAD-GLASS, the coarse common kind used for cottage windows, differs from the others in components and processes. The principal component is the soap-boilers' waste, the viscid mass of unappropriated alkali (barilla or kelp), and the lime employed to render caustic what was appropriated, with salt and sand, which are well dried, mixed with kelp in these proportions—waste 50, kelp 25, sand 25, or 50, 20, 30 (dependent on the sand), which, when coarse, requires 15 to 20 per cent. more alkali; by Loysel stated as 50 to 100, and 20 to 80; then by fritting, prepared for the crucible, into which it is put while incandescent, and during upwards of twelve hours is fused until perfectly vitrified.

BOTTLE-GLASS.—Its composition varies in almost every Manufactory, in which pecularity it much resembles potting. There is constant attention to economy, and consequently it is formed with different quantities of sand, lime, any cheap alkali, or ashes, marle, and even the slag * of iron-furnaces, which has often much lime present with silica. Need it be

* In the quarry at Rowley-regis, from which are obtained the materials which repair the highways, is a basaltic earth, which may be advantageously used in this branch of the Manufacture; according to the suggestions of Count Chaptal, M. Ducros, and the recent experiments of M. Aliot, thus stated :—

"The basaltic earth was decomposed and pulverulent, then put into crucibles, and the heat was that of a potter's oven during 18 hours.

"No. 1, filled with basaltic earth only, supplied a black opaque glass, moderately vitrified.

"No. 2, filled with a mixture of equal portions of basalt, quartz, and ashes, supplied a chocolate glass, lustrous and porcelaineous.

stated that hardness will result. Some Manufacturers use 25 of sand and lime with 75 of soap-boilers' waste; others use 30 sand, 10 kelp, and 60 waste. According to Loysel, the components of the French bottles are—common sand 20 or 22, coarse kelp 8, earth of ashes 30 or 32, wood-ashes 8 or 6, brick-clay 16, and cullet (of bottles) 18 or 16, which purifies free from sandiver or glass gall, and during incandescence as frit is transferred to the pot for use.

Phosphoric Glass (of Bones).—Count Chaptal mentions the production of a glass, apparently only another triumph of Art, but not applicable to any useful purpose: Boil well sound fresh bone; then digest 66 parts in 34 of sulphuric acid, 63 to 72 hours; evaporate dry, and wash in different portions of pure water, till no discoloration ensues; mix, and evaporate these dry; the sediment mix in pure water, and filter out the sulphate of lime, which put into a very large crucible, and, when the intumescence subsides, the glass is formed, of a fine milky whiteness.*

"No. 3, filled with a mixture of equal portions of basalt and sand, supplied a moderately vitrified glass, appearing blue-black, but thin pieces were yellowish-green.

"No. 4, filled with a mixture of equal portions of sand, refuse soda, and basaltic earth, supplied a good, shining, smooth, greenish-yellow, transparent, and well-vitrified glass, well adapted for bottles.

"No. 5, filled with only sand, from the river Orb, where much basaltic earth is present, supplied a well-vitrified glass, apparently well adapted for the fabrication of glass bottles."

When the components of basaltic earth are noticed, silica 48, alumine 16, lime 10, oxide of iron 20, and alkali 4, the cause of vitrescence will appear in the solvent nature of three of the components, and the glass produced is indifferent to corrosive liquids, is harder, tougher, and less subject to flee, which properties are estimable in chemical utensils, retorts, phials, etc.

M. Aliot also formed an excellent bottle-glass, of a yellowish-black tint, interspersed with opaque bluish-white veins, of this mixture: (1) Common sand 62, ashes 32, and soda 6. He also found that (2) Volcanic granite 50, wood-ashes 50, readily vitrified, completely, to a dark lustrous fine glass, well adapted for bottles.

*The salt, when mixed with charcoal-powder and distilled, produces excellent phosphorus.

BRITISH SHEET-GLASS.—This has the like components and proportions as the best crown-glass; but this latter has a waviness which frequently much distorts those objects seen through it, from which defect the British sheet-glass is free, as when looked through from the inside the vision is as clear and distinct as when plate is used, although the outer surface seems uneven (*cockled*). It is made of different dimensions, from 40 × 30, to 50 × 36 inches surface, as required; and from 1-20th to 1-half inch in thickness; but this usually is 1-12th, and crown-glass 1-16th. The manipulations are like those for broad, common or green-glass. The metal is first formed into cylinders of the proper diameters required; next these are brought to the mouth of the oven, and the temperature raised, while the end of the iron tube is closed; the included air rarifies, and expands the cylinder until its weakest part bursts, when instantly the whole surface is opened, carefully smoothed flat, and removed to be annealed. Messrs. Chance Brothers, Birmingham, are the only Manufacturers of this addition to our trade; and likewise of the beautiful square, oval and cylindrical SHADES for clocks and choice ornaments, usually obtained from France, at more than double the cost now charged by this enterprising company.

Crown-glass is not made in France; and only of inferior quality, and to a very limited extent in Germany; yet the German sheet-glass, for windows, is superior to the French and Belgian, both of which excel the British broad-glass. At page 372 I have mentioned the manner in which much sheet-glass is made in Germany for Nuremberg, where it is polished for exportation. Formerly a considerable traffic in this kind of glass was illicitly carried on from Holland by smugglers, and the best specimens of the engraver's art were protected by Dutch glass. Now, however, instead of being necessitated to obtain sheets from Germany, or surreptitiously from Holland, a superior article for home and foreign consumption is fabricated by our countrymen.

One of the Brothers Chance, having business to transact in the French metropolis, indulged in a visit to several of the glass Manufactories in France, Belgium and Germany. Although crown-glass is not made by some of these, and only of inferior quality where it is made, yet in making sheets, the improvements have been progressive in many Manufactories during the last half century. Mr. Chance being very intimately acquainted with the most improved Manipulations of crown-glass making, readily conceived how the improvements of the continental manufacturers might be advantageously employed in the establishment at home; and in 1832 was commenced the fabrication of sheets, surpassing in excellence any previously attempted. Some supercilious party, certainly, may attempt to gainsay any merit for ingenuity or manual dexterity because "*it is his trade.*" Admitted; but we must likewise admit that there have been successfully exerted some mental talent to arrange the suggestions of his inventive powers, some inherent genius to direct the use of his tools in manipulations; and we must claim this as a striking proof of the advantage of possessing as well theoretical knowledge as practical skill, literary information as mechanical ability. Fully aware of the capabilities and intrinsic importance of his Art, and wishful to raise it, and his own character also, the utmost skill and ingenuity of Mr. Chance were exercised to improve the manipulations of his concern, and promote the comforts, and conveniences, and elegancies of life.

The excellence of glass depends, in addition to the components, on good founding, the quality of the fuel, the management of the furnace, the process of fusion, with general knowledge of the manipulations, acquaintance with chemical science, unremitted attention and skill in directing and controlling the operatives, preserving industry, and studied cleanliness in every department; and to ensure successful results, the utmost care and skill of a judicious builder, as well as the best and most suitable materials, are indispensable for the furnaces to be erected in a proper and substantial manner.

Flint-glass, the heaviest, most brilliant, and costly vitreous substance, also much in demand for optical and other philosophical purposes, differs from other kinds, chiefly in a metallic oxide being among its components.* When silica, an alkali, and any metallic oxide are raised to a very high temperature, some time continued, a glass results, but with a tint peculiar to the metal, except only lead and bismuth, with which the mass is bright and colourless: and even excess of lead causes the metal to be slightly yellowish, and inconveniently soft. The object of greatest importance, and most to be regarded, therefore, is (and the remark applies generally to the subjects of this work), in compounding and founding vitreous substances, to employ and bring together precisely those proportions of the respective components which will exactly appropriate and saturate each other.

The foreign *Crystal*, or white glass, is formed of the best white tarso of the Po and carb. potash, in the proportions of 60 and 40. The components are pulverised, then fused, and afterwards raised very high during five hours. This frit is carefully kept. The process of *Glass-Making* is this: The frit is cast into the pot, and the manganese is added to clarify it entirely; the fused mass is either laded out into water, thereby to appropriate all the sandiver, or this is carefully and frequently skimmed off till the mass is purged. The high temperature is kept up from four to six days, arsenic being occasionally added (for reasons assigned, p. 308), and manganese likewise till the *proof* shows metal shining and clear. The late Dr. G. Shaw, when mentioning

*There is recorded in the annals of China that, in A.D. 627, a glass vessel was fabricated at Fokien, and which is still preserved at Pekin, so very large, that to convey it to the Emperor's palace, four cars were used, with upright poles, to which were secured the corners of a large net, into which the vessel was placed; and that a mule can as readily enter into it as can a fly enter into a pitcher. Yet to the improvement of this art the Chinese government is indifferent, although a Manufactory exists belonging to it, in Pekin, and the porcelain trade receives every degree of patronage.

a crystal similar to No. 2, states that the components were first fused, and then as quickly as possible raised in temperature during half an hour; the whole was left 24 hours, then the crucible was broken, and at the bottom was a hard glass, capable of cutting common glass, like a diamond. He adds: "This experiment, duly varied, may lead to several useful improvements in making glass enamels and factitious gems, and shows an expeditious method of making glass without any fixed alkali, which has been generally thought an essential ingredient in glass; and perhaps calcined crystal or other substances, added to the borax, in place of sand, might make a glass approaching to the nature of a diamond."

The article "GLASS" (*Ency. Britt., Edit.* 1835), gives these proportions of components: Sand 40, Carbonate of Soda 35, Cullet 20, Nitre 2, Lime 2, and Charcoal 1 (or 336, 280, 163, 14, 14, 7, in a pot of 814 lbs.), for an excellent metal for crown-glass, and as it can be blown much thinner, and is finer, it is very economical in materials, fuel, time, wages, and excise duty.

	Crystal or Flint.										Sheet.		Crown.		Comn.		
	1	2	3	4	5	6	7	8	9	10	1	2	1	2	1	2	
Sand	59	30	50	54	60	60	60	64			56	66	57	59	60	52	
Minium	—	—	22	16	20	15	—	—									
Potash (carb.)	34	—	18	25	17	10	35	26			23·5	22	28	25	28	13	(†) or
Nitre	5	—	9	5	—	5	5	6			14	8	14	5	—		Soda
Borax	2	70	—	—	—	—	—	—			6·5	1·2	1				
Arsenic			—	—	3	3	*	4			—	2·8	—	2	2	2	
Salt (table)			—	—	—	7	—	—			—	—	—	10	10	8	[ashes.
Manganese	—	—	1	*	*	*	*	*			*	—	*	*	*	25	Wood

The following are in addition to those previously given:—

The reference is to Glass No. 1.—*Balass colour.*—Fuse crystal frit, adding red oxide of manganese; the mass will become clear purple; add the carb. potash gradually to dissipate the manganese.

Black.—Cullets, of different colours, fuse, and add a mixture of zaffre 2 and manganese 1, to supply the colour.

Or—crystal, pulverised, 45, and pulverine 45, lead and tin ashes 8, steel scales 1, and iron ditto 1, raise the temperature very high 12 hours.

Or—crystal frit 92, when fused, gradually add tartrate of potash 2 and manganese 6; fuse 4 days, and then use.

Or—crystal 99, zaffre 10 oz., manganese 3 oz., calcined iron scales 3 oz.

Blue.—Crystal 99, zaffre 14, cobalt 16, manganese 2 oz. (or 1 copper calc), and spice of zaffre.

Sapphire.—Crystal 99, cobalt 14 oz., manganese 2; or Cassius' purple 2 oz. or 99, smalts 1½.

Brown.—Crystal 50, No. 2, 49, calcined iron scales 1: the frit well pulverise, and add glass of antimony 2 lb.

Crysolite.—Crystal 99, calcined iron scales 1.

Carnelian (red).—Crystal 99, glass of antimony 14 oz., sulphate of iron calcined red 2 oz., and a spice of manganese. (White), Crystal 99, bone-ash 14 oz., yellow ochre 2 oz.

Garnet.—Crystal No. 1 and 2, frit 99, manganese 15 oz., zaffre 1 oz., fuse 24 hours.

Or—crystal 99, glass of antimony 1, spice with equal quantities of purple manganese.

Or—crystal 98, glass of antimony 1, and manganese 1.

Gold colour.—Crystal No. 2, 92, borax 1, crude tartar 5, manganese 1, willow charcoal 1. (The carbon produces the tint, says Mr. S. More; Pott used soot and lamp-black.)

Or—with like proportions of nitrate of soda, crude tartar 6, manganese 1, and prussiate of iron.

Or—equal parts of minium, flint, and glass of antimony; or 2, 3, and 2.

Green Emerald.—Crystal 99, nitrate of copper 15 oz., precipitated iron 1 oz.

Or—crystal comp. (4 times fused and cast into water) 30, white crystal powder 2, common glass powder 24, minium 18; fuse 3 hours and cast into water to separate whatever lead happens to be reduced; again fuse the frit 24 hours, then add nitrate of copper and a spice of crocus martis for the requisite tint.

Sea Green.—Fuse best crystal 99, calcined brass 14

oz., zaffre 24 oz., add very gradually, and prevent loss by effervescence: fuse 3 hours, and prove for tint; afterwards raise the temperature during 24 hours.

Purple.—Crystal 99, zaffre 14 oz., purple Cassius 2 oz. (or zaffre 14 oz., manganese 2 oz.).

Red.—Fuse glass No. 3, 36, crown-glass (or green) 70; gradually add red oxide of copper and cream of tartar till the desired tint is obtained.

Ruby.—By repeated solution and evaporation, obtain a red chloride of gold. Crystal glass fuse, and make friable 5 times: then fuse, and add the gold till the tint is obtained.

Or—Frit flint 60, potash 12, nitre 13, borax 15. Again fuse this, and to 66 add of mixed Venetian glass 30, Cassius' purple 4, until the tint is obtained.

Or—Cassius' purple 1, borax 7, arsenic 1, tartar 6, nitre 11, and sand 74.

Topaz.—Crystal 50, gold coloured ditto 50; fuse 2 hours.

Or—Fuse twice over, crystal 55, lead ashes 45, and cast into water; then fuse, frit 66, gold coloured 34.

White.—Crystal 90, bone-ash 10; or 90 flint glass, arsenic 10; fuse carefully.

In filling the glass pots with frit for either flint or crown-glass, the temperature is raised to the highest degree attainable by the furnace. The components for the former gradually diminish in bulk by the fusion, during about fourteen hours required to fill the pot; and for the latter, at intervals of about three hours, till the pot is filled; the very high temperature is continued, according to the nature of the components, forty to forty-eight hours for the former, and twenty-four to thirty hours for the latter; whatever impurities (sandiver or glass gall) arise on the surface are carefully skimmed off; the temperature is then lowered, by closing the doors of the cave, the density of the whole mass is almost homogeneous, and the metal is ready for the workman's manipulations.

Bottle-glass being a compound of the cheapest alkali

and only the coarsest sand (permitted by the excise) varies much in tint; and by addition of crown-glass cullet is brightened for champagne or castor-oil bottles. The soap-makers' waste is calcined about thirty hours, ground, mixed with sand, fritted twelve hours, and while in fusion, at intervals, the pot is filled; the highest temperature is continued sixteen hours, the impurities are skimmed off, the temperature is reduced, the metal increases in density, and the founding is completed. The excess of earthy components and impurity of the alkali, so long subjected to very high temperature, by diminishing the proportion of saline matter present, must be the true cause why green-glass phials excel those of flint to contain corrosive fluids.

The Glass Pot is formed of the best Stourbridge clay, 75 parts, with 25 of a fine powder of old glass pots, for reasons assigned (p. 461). The best kind of clay is quarried at Amblecote, near Stourbridge, in a stratum thirty inches thick, forty-five feet below the coal, and 150 feet beneath the surface. There is a necessity for the clay employed to be the most refractory that can be obtained, as free as possible from calcareous and ferruginous impurities. In proportion to its *fatness*, or excess of pure alumine, will be its fitness for appropriating a determinate quantity (among the foreign Manufacturers 40 to 80) per cent. of the powder of old glass pots, or of well-baked portions of the clay itself. The following method of determining the composition of glass-pot clay, and likewise the suitability of the native earth, was first proposed by Mon. Bosc. d'Antic: "In very different proportions mix the crude earth and the powder of the baked portion, etc.; form these into cakes precisely of the same dimensions, length, width, and depth (4, 4, and 1 inches); slowly and carefully dry these, and next bake at an extremely high temperature, until their bulk ceases to experience any change in solidity and contraction. Let the whole be carefully inspected, and that composition will be the best whose bulk has been diminished *only one-eighteenth part*." A man carefully treads mass into a tenacious paste, that is made into rolls, which

in successive layers carefully and closely compacted form the receptacle of the metal; no air-bubble remains to expand by heat and cause a rupture. Now that adequate mechanical power is applicable to the throwing-wheel at Etruria (Wedgwood's), and at Stoke (Copeland and Garrett's), to move the heaviest mass of clay requisite for the glass pot—and there are throwers with sufficient skill for the proper execution of the task—I think there would be economy in bringing the fabrication of the Glass Pot within the sphere of the Potters' Art. During nine to twelve months the pot is subjected to a temperature of 50° × Fahrenheit; then for one month to 90° × ; next it is gradually raised to that of the furnace, into which it is removed with all possible celerity, to replace any which may have failed.

Glass-staining and Painting.

To produce glass perfectly colourless requires much experience and notice of the chemical causes of the change of tints that would early occur, which latter would suggest the method of obtaining any desired tint by introducing the requisite metallic oxide into the mass during fusion, as was the *pot-metal* of subsequent times. The production of coloured glass, therefore, is reasonably considered as coeval with the Manufacture itself, however early; but of recent date, compared with that, although not determined, is the art of depicting objects by small pieces of *stained* glass, or by colours *painted* thereon. During several centuries it gradually improved in excellence, in mellow rich tint, and calm imposing grandeur of character; but it has remained for our day to have historical subjects, specimens of the Art, of distinguished excellence for accurate design and details, suitable breadth of surface, delicacy of tints, and truth of effect; demonstrating the possibility, by combining the varied excellences of early and recent artists, of producing triumphs surpassing

any hitherto achieved, and for which is wanting only adequate public encouragement of artists of inventive genius and practical skill. Without this we cannot reasonably expect them to forego the pleasure, as each stroke of the pencil renders the design more obvious, and the success and patronage which adherence to the palette and canvas secures; and to pursue that study which supplies the best exhibition of taste, yet has the disadvantages of expensive materials, tedious and precarious processes, and anxious fear for the injury of his tints by the high temperature of the kiln. It is a matter of prudence to prepare of each colour a quantity adequate to the completion of the design, that the beauty of the whole may be preserved by superseding the liability to change of tint from several preparations.

In this Art may every variety of pictorial design be executed. As modern ingenuity combines the requisite tints of the subjects on the same sheet of glass, and incorporates them therewith by raising the temperature till the components fuse together—for landscapes are afforded peculiarly powerful contrasts of light and shade, and for flowers all the splendour and delicacy of tints exhibited in Nature. And with the advantage of being indestructible, except by violence; all the *Colours* and *Stains* used being either metallic oxides or minerals, which during the raised temperature incorporate with, and penetrate the substance of the glass; the former, semi-transparent, dosed with a flux, promote combination with the surface; the other permeate the glass, without injuring its transparence. The components of the best crown-glass most readily combining with metallic oxide, our artists usually employ it. I have not been informed of any using British sheet-glass. The *Stains* are only three: *Orange.*—Fuse together pure silver 66, antimony 34; pulverise and grind 14 of frit with Venetian-red 86. *Red.*—Add to the above 99, sulphuric acid 1. *Lemon-yellow.*—From the nitric solution of silver precipitate the metal by test 26; of this precipitate add 8 parts to 82 of pure alumine, and mix well for use in

distilled water; then evaporate to a proper consistence for use (or alter the alumine for change of tint).

The judicious inspector of these productions will denounce as erroneous, unjust, and absurd the opinion resulting from indiscriminate fondness for the antique, that excellence is confined to the productions of the 14th and 15th centuries, in brilliance of tint, and grandeur of character; for, with the like tints, equally brilliant, rich, varied, and durable, are many others, then not used, probably because not known; as pink, pale lemon, and several compound colours. The ancient ruby-tint alone remains unequalled.* The artists possess all the resources of their predecessors, and likewise other facilities, for excellence; they are better acquainted with the principles of the science of drawing, and the fluxes proper to adapt different colours for using on the same sheet, so that every requisite tint can be introduced, and instead of scores of small pieces as formerly, a few sheets only are needful for the design. By patient and attentive study of the isolated magnificent old English, or pointed style, as exhibited in remains, and the invaluable elucidations of able antiquaries and draughtsmen, our artists will be prepared to give all possible effect to their embellishments of noble edifices, without the liability of failure consequent on attempting to enlist the principles of the Greek and Italian schools into

* Boyle mentions the accidental production of this tint. In a letter on imbuing glass with metallic colours, he details his own experiments to obtain the ruby-tint, and then mentions an artist, who, desirous to effect some purpose with an amalgam of gold and mercury, attempted to form it by keeping the two metals fused together in a glass retort, which after some time burst with a tremendous explosion, and the fragments excelled in fine ruby-tint any Mr. Boyle had ever seen.

Kunkel, in 1670, made a cup and cover of ruby-coloured glass, still preserved and very highly valued at Berlin. Another, most prized by its maker, is 1 inch thick and 24 lbs. weight. He states, that frit of best glass 999 and purple 1 will give the full rich ruby colour. Recent experiments prove, however, that to 86 purple must be added 14 of the white oxide of antimony. The better the quality of the former, and the purer the latter, the more beautiful will be the resulting tint.

their service, for figures, groups, foliage, etc.; and by avoiding the gaudy, vulgar, deep tints when executing the strong varied outlines will the specimens become all that is desirable.

Engraving on Glass. — The glass most esteemed throughout Europe, in the 16th century, had the name *Venetian*,* because made at the village of Murano, nigh the city of Venice. The mirrors especially were in great demand, and by their excellence superseded those of metal. The sheets had designs executed on them with the diamond, an acid liquor capable of corroding glass not being then known. Professor Beckman (in his *History of Inventions*) ascribes this latter method to Henry Schwanhard, a celebrated glass-cutter of Nuremberg, who, in 1670, accidentally corroded and rendered quite soft his spectacles by some *aqua regia* so called, thereby suggesting a method to readily execute designs or writing on sheets of glass. The learned Professor's opinion is well grounded, that Schwanhard had discovered and used, as did likewise his pupils, for this purpose, the substance now named fluoric acid; for his method was, to correctly draw out the design with a proper varnish, that would preserve all the figures and tracing from the action of the corrosive acid, which affected all the surface contiguous to them, leaving them smooth, clear, and in relief on a dim ground when the glass was cleaned; whereas the practice

* The glass-works at Murano now make tubes for beads. The workman takes a portion of each of the coloured glasses from the pots, which after being well twisted or rolled together, is blown into a cylinder; a second workman then attaches his instrument to the other end, and on a gallery 150 feet long, they run in opposite directions and form a tube, whose diameter accords with the quantity of the metal taken up at first. The tubes are sorted accordingly; then chipped into sizes which are agitated among sand and wood-ashes in a bowl, till the aperture is filled; next in a metal tray, and with more wood-ashes and sand over a charcoal fire they are constantly agitated, till they are spherical; afterwards they are separated from the sand and ashes, and thrown into sieves of varied meshes, to determine the sizes.

of our day is to varnish the surface with isinglass-size or oil of turpentine and ceruse. At Beckman's suggestion, some artists verified satisfactorily the process subjoined, conjectured to be that of Schwanhard and his pupils, communicated to Kruntz, and by him published in the *Oekonomische Encyclopädie*, 1725.

"When the *spiritus nitri per distillationem* has passed into the recipient, ply it with a strong fire, and when well dephlegmated, pour it, as it corrodes ordinary glass, into a Weldenberg flask, then throw into it a pulverised green Bohemian emerald, otherwise called *hesphorus* [the green fluor spar, says Beckman], (which, when reduced to powder, and heated, emits in the dark a green light), and place it in warm sand for 24 hours. Take a piece of glass well cleaned, and freed from all grease by means of a ley; put a border of wax round it, about an inch in height, and cover it all over with the above acid. The longer you let it stand, so much the better; and at the end of some time the glass will be corroded, and the figures which have been traced out with sulphur and varnish will appear as if raised above the pane of glass."

The Manufacturer will find his account in preserving correct standards of his productions; variation from which, in specific gravity, will prove a change, and likewise the remedy, in the proportions of the components. As glasses with these of only silica and alkali, or silica and minium, at determined temperatures, with the additional quantity of alkali, or of oxide, increase their specific gravity, then, from knowing the varied proportions of components, and difference of specific gravity of two kinds of glass, may be determined, of a third, the specific gravity, by the alkali, or oxide, present, or these by the other respectively.

No. 1,	of silica 80,	alkali 20,	has 236 specific gravity			
— 2,	—— 54,	—— 46,	— 254	——	difference 26 & 18	
— 1,	—— 27,	Minium 73,	— 520	——		
— 2,	—— 11,	—— 89,	— 657	——		16 & 137

From these data, to determine the proportions of the like components, for glasses No. 3, with specific gravity 242 and 579: As the difference between the specific gravities, also the weights of oxide, of the glasses 1 and 2, = 18 and 16, is to that between the weight of oxide, and specific gravity in 1 and 3 = 6 and 7, so is the difference

between the weight of alkali and the specific gravity in 1 and 2 = 26 and 137, to the difference between those of 1 and 3 = 9 and 59. Adding each number to that of the alkali, and the oxide, in 1, the glasses 3 must be silica 71, alkali 29, and silica 20, minium 80.

The presence of lime greatly increases the specific gravity of glass; whenever, therefore, this property exceeds the standard adopted, excess of either lime or alkali is present, and needs to be appropriated.

Flint-glass combines silica, minium, and alkali at a temperature lower than those at which the other kinds are founded. The specific gravity of glasses from various compounds is determined thus: When at the like temperature silica 76 and alkali 24, or silica 24 and minium 76, chemically combine, the glasses have the specific gravity 24 and 54. And the glass from either the raw components, in these proportions, or equal weights of the two preceding, properly founded, has that specific gravity deduced by calculation (unless a difference be caused by corrosion of the glass pot). Supposing that at a certain temperature the silica appropriates one portion, the minium, and the other, the alkali requisite for perfect vitrification, excess of the latter being dissipated, the specific gravity can be thus determined: In using silica 100, minium 50, potash 40, during the founding, the minium is reduced to 48, which is appropriated by 16 of silica, forming glass 64, with specific gravity 54. The potash 40 likewise is reduced to 28, which is appropriated by the silica 84, forming glass 112, with specific gravity 24. Were the raw components founded, the loss of minium 2, potash 12, leaves 176 of glass, of the specific gravity determined thus: Multiply together the 54 and 24 of the two glasses = 1296, and this by the weight 176 = 228,086, which divide by the product of multiplying respectively their weights and specific gravities, 7584, and the specific gravity will be 30·13, when the founding properly succeeds. The verification this affords of the principle given, p. 48, is to myself very interesting.

The facilities for communication have so generally diffused current knowledge, that the artisan in his workshop, equally with the student in his closet, has thence delightful employment and invigoration of the mental faculties, capacitating for ready appropriation of other stores, or the practice of any suggestions, by which he may become a more skilful workman, also a more useful and better member of society.

The solution of the problem—To make (for optical purposes especially) glass homogeneous, transparent, hard and refractive—has excited the ingenuity and attention of many glass-makers. Mere mechanical *mixings* were as successful probably as could be expected, but the uncertain composition of some of the materials may render the theory uncertain, and by incongruous appropriations preclude the desirable and indispensable data. We expect these to be clearly ascertained, because much important information has been elicited for future guidance. Invited by the Royal Society, Dr. Faraday brought his great experimental skill to its investigation, with considerable advantage to the art. His *rough-glass furnace* is an interior iron box, 8½ inches deep, 14 wide, and 30 long, lined with refractory fire-bricks; in the bottom is fixed a grate, 12 by 8 inches; at the front is a common furnace iron door, and in the end is a funnel-pipe to enter a long flue; on the lining rests a perforated iron cover for receiving the crucibles. The fire-chamber is 12 inches square, 5½ inches deep, with sides 2 inches thick. The crucibles are 5 inches high, with the bottom diameter 3¼ inches, and the top 3½ inches, of the finest and most refractory porcelain, as thin as will safely sustain extremely high temperature. The covers are 4½ inch evaporating basins, slung in platina wire, with a loop for removal by an iron rod. The materials are, nitrate of lead 154·14, silicate of lead 24·00, and crystallised boracic acid 42·8; the coals are ignited, and all the space around is filled with coke. As the composition condenses by rise of temperature, successive additions are made, and the whole is carefully agitated during two hours to prevent the

defects named striæ, threads, tears, and knots;* and the highest temperature the crucible will bear is continued some hours, until it ceases to evolve even the most minute bubbles of gas or vapour. The better to promote this a portion of spongy platina and of materials are first well mixed together, and afterwards mingled with those of the mass, prior to filling the pot; and the infusible metal, as a nucleus, during the rise and agitation of temperature, causes all gas or vapour to evolve, and then completely deposits. The rough glass is either removed with a platina ladle into platina trays, or cast into plenty of distilled water in a very deep flint-ware jar, by which it is much divided; next it is drained, dried well, and preserved in clean bottles. The *finishing furnace* is a parallelopiped of brick-work, with a fire-chamber 25 inches by $12\frac{3}{4}$, beneath which is a receptacle for coke, also the flue for the passage of the flame and smoke from the fire-place at one end; and in the ash-pit, a sheet-iron trough filled with water, constantly prevents clinkers closing up the bars of the grate. In the fire-chamber is properly secured a tray, of suitable size, made of the best platina, carefully rolled, so that 1 inch weighs 17·5 grains, and without the smallest hole. When spongy platina has not been already used, it is triturated with powder of the rough glass, and mingled with the remainder. The tray is filled with the rough

* *Striæ* are undulations in the glass from incongruous particles of the components, equal to the other portions in transparence and vitrescence, separating perfect portions, and bending or refracting the rays of light, so as to distort the appearance of objects viewed through them. As these objects are necessarily much magnified by optical instruments, equally so will be the distortion by even very minute defects in the glass, which consequently precludes the accuracy of vision designed to be obtained. Only when very obvious, however, are striæ detrimental to the glass used for the usual purposes of society.

Threads are the greenish fibres in glass which by change of temperature dilate and contract, caused by particles of clay remaining unappropriated by the temperature, rendering the mass extremely fragile.

Tears form the greatest imperfection in glass, caused by portions of clay from the dome of the furnace, or arch, dropping into the pots and

glass and covered, while the temperature is raised during about one hour; the mass is then carefully agitated, and likewise often during two hours more; and a very high temperature is attained and continued from 6 to 12 hours after the whole mass has assumed a state of perfect repose. From the quantity mentioned, Dr. F. obtained glass 152; of protoxide of lead 112, silica 16, dry boracic acid 24, with specific gravity 5·44, or with borate of lead 6·4. The hardness is a result of minimum of lead, with borate, soft; biborate, harder; and tri-borate, hardest, equal to flint-glass; silicated borate, softer than flint glass, which last is equalled by a glass, of minium 30, oxide of silver 28, boracic acid 42, of much excellence in colour, and increased fusibility. Sir J. Herschel's three experiments demonstrate that Dr. F.'s glass, equally with flint-glass, corrects the dispersive powers of crown or plate-glass, in ratio of the specific gravity:—

	Bor. Lead.	Sil. Bor. Lead.
Angle of glass prism..... =	29° 6′	30° 26′
Refractive index for extreme red rays μ =	2·0430	1·8521
Ditto maximum yellow..... =	2·0652	1·8735
Ditto extreme violet..... =	2·1223	1·9135
Dispersive index = $\frac{\delta\,\mu}{\mu - 1}$.....	3·0740	0·0703

being partially vitrified with the glass, which it renders so brittle that instances have occurred in which it has cracked by unequal expansion from slight change of temperature.

Knots are caused by aggregation of particles of silica imperfectly vitrified; or portions of glass-gall left when skimming the pot; or fragments of the pot or furnace accidentally abraded by the tools or other cause.

Bubbles are caused by portions of gas which evolve during the founding, but have not been dispersed, because the glass has been too tenacious, owing to either deficient temperature or excess of silica. The appearance is their chief defect; for even when numerous, the sum of their areas united is only a small proportion of the whole surface of the glass; and each acts as a small convex lens, rapidly turns aside the rays which strike against it, and slightly diminish the light in proportion to its area.

CHAPTER III.

COLOURS.

The first attempts at artificially combining with subjects, colours not previously present, were anterior to any known record thereof, and originated in the desire to gratify natural fondness for variety and finery. Man, rude or polished, reared in the wild or the palace, feels a sense of pleasure while regarding the splendour of coloured subjects in which lively tints are displayed and contrasted, as in the endless variety of the parterre, and the delicate plumage of the songsters of the grove; and in the less cultivated state he would attempt to colour apparel or utensils with some production supplied by Nature. The colours thus obtained at some sacrifice of time and trouble would be some permanent, others evanescent, and their application rude and imperfect, yet suggesting new ideas by the defects, and fresh efforts by the failures, because of ignorance of principles. Progress in refinement would introduce fresh methods more successful, and with the aid of fresh materials gradually urge onward the Art itself, until it assumed the importance which it still enjoys, as a

source of respectability and opulence to some, and of employment to numbers.

I am not required to determine the priority of application of metallic oxides to colour ornaments or transparent glass. The employment of vitreous colours at a very early date by the Egyptians is demonstrated by the beads found on many of the bandages of their mummies, and preserved ornaments, fabrications of the early Greeks, Romans and Saxons, proves its practice by those people. Glass is known also to have been a very early Manufacture; and almost coeval with its commencement (whether by accident or design is not of moment) was its differences of colour. There is great probability that it was the result of mere accident; stated to have been that some sailors having made a large fire with dried marine vegetables on the beach, the alkali and silica combined and fused into clear glass.* That both methods were early pursued both in Egypt and Phœnicia, cannot with propriety be questioned, though we remain unacquainted with the processes, of whose perfection we judge only from its capability of answering deceptive purposes.† These necessarily involve some acquaintance with the chemical properties of metallic oxides for producing the colour desired; and still their ignorance of the mineral

* "Fama est, adpulso nave mercatorum nitri, cum sparsi per littus epulas pararent, nec esset cortinis attollendis lapidum occasio, glebas nitri e nave subdidisse. Quibus accensis, permixtu arena litoris, translucentes novi liquoris fluxisse rivos; et hanc fuisse originem vitri."—PLINI, Nat. Hist. lib. xxxvi. cap. 65.

† Thus denounced by Pliny—"Adulterantar vitro simillime! sed cote deprehenduntur, sicut aliæ gemmæ factitiæ.

acids in our day best known as the proper and readiest solvents of oxides renders the determination of their means and manipulations a difficult task.

Klaproth's analysis of 200 grains of *antique* red, yellow, and blue glasses, gives these components and proportions :—

	Red.	Yellow.	Blue.
Silica	142	130	163
Alumine	5	11	3
Lime	3	13	0·5
Oxide of lead	28	15	——
——— Copper	15	20	1
——— Iron	2	7	19
	195	196	186·5

The green glass has precisely the same components as the red, only varied in proportions, and with peroxide instead of protoxide of copper. Similar specimens of red and blue enamels often occur in the scoriæ of the copper and iron smelting furnaces. But the problem of their production we cannot solve, because not sufficiently acquainted with the circumstances and conditions, like as of those by Nature adopted that iron may tinge the sapphire, lapis, lazuli, blue clays, etc., in which Klaproth detected it; and Gmelin has proved its utility for tinging glass of a beautiful blue, suspected by Delaval to have been produced by cobalt, though this was first so employed about A.D. 1540, by Christopher Schurer, glassmaker, Platten.

To every reflecting mind the fact will be clear, that the application of principles will approximate to perfection the preparation of vitreous colours, without

denying that in their absence, and disregard of a correct theory of chemistry, repeated mixing of ingredients patiently pursued must have credit for the high degree to which the Art has attained. When intelligent artisans direct the processes, and fully detail the results to philosophers, its progress will be rapid, certain and "onward." The observation of any new fact becomes a matter of general concern, and demands philosophic consideration when its influence is likely to extend beyond the single circumstance to which is owing its discovery. Only when directed by principles can the artisan's skill and attention, in adapting the proportions of the different components, and his labour in the peculiar manipulations, for the numerous and diversified colours, be most economically and profitably employed in this extremely important and interesting branch of the Manufacture.

COLOUR-MAKING.

In this the improvements in the supply of the palette will accord strictly with the employment of bright colorific oxides, not changeable by the components of the glaze. Their reciprocal combinative potencies, and difference of orbital spaces, adapt them for combination respectively with certain momenta, till their progress or deeper penetration into the glaze from the surface ceases, or is interrupted, because all potency is appropriated.

Metallic oxides are the only substances employed as the bases of vitreous colours; and among Nature's

vast supply, many can be rendered useful for the purpose; as, by proper preparation, they give to any vitreous surface a brilliance of tint, and to glass a rich beauty, almost equalling that of natural gems. Seldom are the oxides used alone, and all oxides, even of the same metal, are not always useful as substantive colours, though as components they are available, because of the change consequent on baking the enamel, as the yellow oxide of gold, the black and green oxides of copper, the puce and red oxides of lead, the oxides of mercury, arsenic, etc.

ENAMEL strictly signifies—a delicate white opaque vitreous compound applied to a metallic recipient, from which its import is extended, in this Manufacture, to a vitreous compound of metallic oxides and silica, susceptible of the most beautiful and brilliant tints, whether opaque or translucent; while the porcelain glaze itself is, by its delicate whiteness and beautiful texture, especially adapted as a ground, superior to any other for preserving the delicacy, strong brilliance, and richness of tint, of the finest efforts of the pencil.

The properties of chrome, cobalt, copper, iron, lead, manganese, gold, tin, etc., have been long known; and interest has induced acquaintance with the metallurgical processes usually adopted for their treatment; but chemistry has not yet shed the rays of her lamp sufficiently on them for the transpiring facts to be adequately explained by theory. The preparation of these metals as colours involves many difficulties, because their purity and lustre must be preserved with a fusibility at a temperature which does not destroy the combination of the components

of the enamel, yet softens the compound sufficiently to commix with the glaze. Alone metallic oxides do not fuse, though at a very high temperature they are appropriated by the glaze, usually with a very dull tint. To prevent this dullness, the components of the glaze are regarded in the mixture of substances with these oxides as a *flux*.

The colours employed on enamel are the earliest, except those of Nature. When used for soft porcelain and flint ware, they need less flux than for the hard, because the recipient silicate of lead, or of borax, readily softens and appropriates the metallic oxides and alkaline components. The lead and borax fluxes are useful in their respective applications, and facilitate the employment and fixing of the colours. But as borax does not dilute with gum, it is not a component of the flux of those colours which are ground up with gum-water.

Changes in the beauty of the tints arise from two causes—not from their composition, but the nature of the recipient, and the baking. The oxide of lead in the glaze affects several of the colours, as those of iron, in a remarkable manner.* The enamel baking softens the glaze for the colours to easily combine; and whenever they become diluted by such combination, as often occurs, the baking changes into a slight sketch the painting which seemed finished. Hence only are the needful strength and brilliance of tint obtained by frequent re-touchings and bakings, by which the colours are no more distinguishable,

* Brongniart has the merit of first publishing this fact, which had caused such losses to the Staffordshire Manufacturers.

than when applied to canvas. Certainly they are always soft, but they never scale off and injure the design.

The hard porcelain having for its base the very white alumine, called kaolin, mixed with a silicious, calcareous, and alkaline solvent (hence the alumine preserves almost the natural tints which acids always modify), and whose glaze is only the fusible felspar, fused with only borax and barytes (not an atom of lead), requires two kinds of colours, the one many and varied for representing different subjects, of almost like components with those for soft porcelain, and by the additional dose of flux adapted to bake at a temperature many degrees below that required to bake the glaze ; the other a few technically named *grounds*, applied to the general surface, bake at a temperature only a few degrees below that for the glaze.

The temperature needful to bake the colours expands the orbital spaces of the components of the glaze, by which portions of the flux and colorific oxides are appropriated, merely with a diminution of their strength by transparence ; the glaze not becoming semi-fluid, and so appropriating deeply and changing the colours. When great care is employed in adjusting the equivalence of the alkali introduced, seldom does the annoyance ensue of *scaling off* of the colours required for finishing the design by repeated touchings and bakings. There being only the proper quantity present for affecting the glaze, no extra volatilisation of alkaline particles occurs to injure the tints. The proper mixture of the colour on the palette prior to using, and a due portion of lime

in the glaze, and of flux in the colours, will generally prevent the unpleasantness of *faint* designs. As only few metallic oxides do not volatilise but remain fixed and unaltered in tint at the high temperature needful to bake the glaze of hard porcelain, only few colours can be employed as grounds for the general surface, yet chemistry will determine their economical employment and kinds. When their solvent is felspar, they incorporate with the glaze, acquire extra brilliance, and never craze.

Pure water is preferred in grinding, or rendering sufficiently comminute, the colours, because in it they grind freely and readily, and therefore are more efficiently reduced, and yet separated from any impurities that are divided and carried off by evaporation. The presence of volatile components, as when litharge is in the water, must be regarded by the grinder, because the noxious effluvium is injurious to the lungs. In proportion to the requisite degree of comminution must be the quantity ground at the same time, because the finer it is required, the smaller must be the quantity brought under the action of the muller (as fine gold, for instance). When substances are introduced merely to modify the colours, they are mixed in very small quantities till the required tint is obtained.

Brongniart recommends to take the enamel from the crucible;* first fracture the lumps small by a

* Crucibles for the fusion of metals only have black lead (carburet of iron) intimately mixed with Stourbridge clay, or the white marle of Shelton and Hot-lane. As this is refractory at any temperature, yet without combinative potency with the clay which protects it from the action of the atmosphere, the crucible is

hammer, then pulverise in a mortar to a fineness which will pass through a sand sieve; then well levigate, and carry over, by stirring the fluid, the fine powder, which must be left to subside; again pulverise the calc, and repeat the process until a sufficient quantity of fine powder is obtained; and the remainder will have different degrees of fineness in the respective portions.

Various compounds are used to promote the fixation of the metallic oxides in the glaze of the ware; and because of more easy vitrescence, during the baking of the colours, are called *hard* or *soft fluxes*. These, when carefully adapted to the components of the colours, and of the glaze respectively, preclude dissatisfaction and disappointment, as well

incombustible, less than any other compound affected by the raised temperature, yet without retaining, as do the sides of other crucibles, any portion of the fused substances. But for saline substances other arrangements are made. Well-*weathered* marle, which has been exposed to the action of the atmosphere, worked by manual labour upon a suitable plot of land, several days in succession, and is usually passed between strong iron cylinders. This marle 50 parts, flint ware shards 25, and coke in powder 25, are well mixed together by sifting; then water is added as needed, and the mass is beaten with mallets till well solidified. To form the crucible, a lump of this is placed in a well-oiled sheet-iron mould of the required size and shape; into this a suitable-shaped piece of hard wood of the proper form is forced by the screw-press, or the squeezing box; thus readily is obtained at once a crucible, and afterwards each is carefully and slowly dried; and when properly used, they will repeatedly bear, without failure, a very high temperature. This method will form the *best* crucibles; and the size as well as the thickness may thus be readily secured, from 10 inches high and 8 diameter, to 2 inches by $1\frac{1}{2}$, tapering gradually to the bottom.

as sacrifice of time, labour, expense and credit with the purchaser. It will be found that scarcely any colour requires so large a dose of flux as 6 to 1, which enveloping the metallic base or oxide, promotes its vitrescence at a heat below what would destroy its splendour, fixed and rendered permanent on the porcelain. The varied heat proper to fuse different oxides with fluxes renders requisite care in apportioning the flux, so as to preserve the brilliance in even the finest lines; and when properly observed, the ware presents the softness of the richest velvet, and the lustre of the most beautiful satin, without the possibility of decomposition.

COMPONENTS AND PROPORTIONS OF FLUXES :—

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	
R. lead	18	17	35	36	50	50	46	...	41	28	48	...	30	...	50	50	42	63	62	50	...	...	...	
Flint	48	50	25	14	15	40	12	18	...	...	15	...	40	53	...	...	...	...	...	9	6	11	9	Nitre
Borax	34	33	40	50	35	10	9	34	23	17	30	10	36	25	6	32	42	8	6	...	30	39	36	
Cullet	...	...	...	...	...	...	33	...	36	55	7	70	4	...	12	1	2	4	4	9	14	...	9	Potash
W. lead	...	...	...	...	...	...	...	50	...	...	...	20	...	22	32	17	14	25	28	32	50	50	46	L. sand

The flux is employed to secure to the respective tints, after baking, strength, brilliance, and permanence, by the enamel being homogeneous with the glaze; to preserve from further separation the comminute particles of the metallic oxide; to protect the tints from atmospheric action; also, to promote combination of the enamel with the glaze at a temperature much lower than was required for its baking; and, by a precise supply, to preserve the tints from injury.

COMPONENTS OF THE COLOURS.

The best colours now used in the Art have these components : Reds, oxides of gold and iron ; Purples, oxides of cobalt, chromium, tin and calcium ; Pinks, oxides of chromium, calcium and tin ; Browns, oxides of chromium, iron and manganese ; Blues, oxides of cobalt and silica ; *mat-blue*, oxides of cobalt, lime and zinc ; Yellow and Orange, oxides of lead, silver and antimony ; Greens, *yellow* or *emerald*, oxides of chromium and silicon ; *blue* or *celeste*, oxides of chromium, cobalt, silicon and zinc ; *green-edge*, oxides of copper and chromium ; Blacks, oxides of cobalt, nickel, manganese, chromium and iron.

Reds, etc., *obtained from Gold.*

There is indispensable an accurate detail of the precise proportion of components, also of the several processes for the production of the simple colours, that each may be fine and clear, yet sufficiently fusible to freely bake with the glaze.

Gold was named by the alchemists the king of metals ; and after a solvent was discovered, it was distinguished as kings'-water, or *Aqua Regia*. Several compounds, however, now bear this name, and as their components differ much, even when applied for a specific purpose, they are submitted to the reader. The liquid itself is strictly a medium for the metal to

be in that condition in which it will have reciprocal potency for combination with chlorine. Nitrous acid saturated with nitrous gas has been mixed with concentrated muriatic acid; but because devoid of reciprocal potency, the effect was as feeble as would have been that of the nitrous gas on water, and the mixture was inert on gold and on platinum.

1. Muriatic acid of the strength 1·162 treat with nitrous acid vapour until saturated. 2. (*Henry*) Nitric acid of the strength 1·42, 66 parts, and 34 of muriatic acid at 1·149. 3. (*Proust*) Nitric acid at 1·45, 20 parts, and 80 of muriatic acid at 1·139. These proportions also are directed by Gray, but the strengths are 1·42 and 1·128. 4. Nitric acid at 1·392, 33 parts, and 77 muriatic acid at 1·149. 5. Nitric acid at 1·145, 66 parts, and 34 muriatic acid at 1·139. 6. (*Keir*) Sulphuric acid at 1·80, 50 parts, nitre 25, and table-salt 25. 7. Sulphuric acid 67 parts, nitric acid at 1·392, 33, and saturate with table-salt. 8. Nitric acid at 1·15 saturate with table-salt.

The *aqua regia* must be of the specific gravity 1·062, or higher, for most efficiently and economically dissolving gold, and will be readily ascertained by using a phial that holds exactly *four ounces* of distilled water, and when filled with acid contains precisely *four ounces and a quarter* thereof. When below this, carefully must the liquid be evaporated to the requisite strength. The temperature also must be raised—1 and 4 to 80° Fahrenheit; 2 and 5 to 100°; and 3, 6, 7 to 110°. Although the acids may be colourless (seldom in those of commerce), the mixture will be primrose-yellow, and the tint will grow deeper while the temperature is raised, because chlorine evolves; the darker it is, the more diminished is its combinative potency with the gold; consequently, much attention is needed to the degree and heat, and its continuance.

Solution of Gold.—To the *aqua regia* add a small portion of grain gold, and when it is dissolved, repeat the dose, until saturation is nigh; then diminish gradually till no more is appropriated by the acid. Ascertain the quantity of gold in the solution, and the specific gravity of the liquid, for a standard in future.

Solution of Silver (for the Purple).—1. In pure water 50

parts, and 50 of nitric acid of the strength 1·145, at the temperature 110°, add doses of grain silver as directed for the gold. Keep in the dark this solution.

2. *Aqua Reginæ*, Queen's Water (and the only bath in which the Queen of Metals can wash herself free from intrusion). To sulphuric acid at 1·80, 88 parts, add 12 parts of nitrate of silver after it has been in solution in pure water, and re-crystallised. Water is not required for silver, but must be added, 66 acid to 34 water for other metals. The mere heat of our furnaces does not oxidate silver; and its extreme indifference to the presence of oxygen, even when it has been supplied by acids, is only counteracted by employing an easily vitrifiable substance, which appropriates the oxide as it is formed, at a temperature incapable of reducing it to the metallic state.

Solutions of Tin.—1. The *aqua regia* 5 or 8, at 112° Fahrenheit, saturate with small and repeated doses of grain tin. 2. Muriatic acid at 1·149, and temperature 112° Fahrenheit, saturate in a similar manner; but *always in daylight*, because hydrogen evolves during the process, and the flame of a candle would be liable to cause a dangerous explosion. This solution is excellent, because it does not coagulate. 3. (*Berard's Method*, see p. 357). 4. To muriatic acid (at 1·149) 60 parts, add nitre 40 parts; and when fully dissolved, to 67 of the liquid add 33 of grain tin, cover close to exclude the oxygen of the atmosphere, and keep the temperature at 100° 3 hours. When the metal is in solution, the unappropriated chlorine will solicit nitre 20 and tin 20 parts additional; then to 60 parts solution add 40 of water, and keep the temperature at 110° 24 hours.

Carmine or Rose Colour.—This beautiful colour requires much attention in its preparation to secure all the possible brilliance of tint; and in its application, to prevent injury from excess of heat in baking, or from the gas of either carbonic or sulphurous acid. The colour is prepared by this process: The solution of gold is brought into combination with ammonia by any of the usual methods; the muriate

of gold is decomposed by ammonia, or an ammoniacal salt; or it is kept in a dark and damp place where the air is stagnant. Mons says: "I prepare it with most advantage by precipitating, by potash, a diluted solution of muriate of gold and muriate of ammonia." In pure water at 190° Fahrenheit, 95 parts, and solution of gold 5, add sal ammoniac until precipitation ceases; then add a little more, and let the liquid repose 48 hours. By siphon draw off the liquid; and when the colour is not immediately wanted, wash it in great excess of boiling pure water, and again let it repose 48 hours. It is best dried on bibulous paper on a plaster slab, and a feather will brush it off the receptacle.*

This preparation is fulminative, and will explode most violently and dangerously, because of the presence of the fulminic acid, when the temperature is raised to 420° Fahrenheit, a little lower than that at which tin fuses, and also by moderate friction; but the presence of a fixed alkali neutralises the acid, and exposure to a heat of 212° some hours will adapt the colour for being applied with safety. No acid or alkali will decompose this salt, the oxide possessing the potency of an acid, and the ammonia that of an oxide.

Another preparation of gold, more easily and

* I have noticed what I deem something remarkable, that by precisely pursuing the manipulations mentioned in many published formulæ, the colour-maker will not be able to supply the colours of which they profess to be recipes. They merely mention a part of those which must be performed, and leave them to suggest the remainder, for the person himself to discover—if he be able.

with safety managed, and for many uses of equal strength, is the brownish-yellow (not fulminative) precipitate, by adding carbonate of potash to the diluted solution of gold when the *aqua regia* is one of those already mentioned, and free from ammonia.

COLOUR.—Mix precipitate 75, chloride of silver 25 parts; then grind colour 14 with flux (22) 86 parts. (The flux will depend much on the glaze.) At first the colour seems a dirty violet, but baking renders it a beautiful carmine. On all soft porcelains, and with all artists, this and the purple cannot be changing tints; but it alone changes on hard porcelains, because of baking. The pernicious effects of fire preclude the formation of the basic oxide and the flux or solvent into a frit prior to using. (See the *Reds* from Iron.)

PURPLE.*—To gold solution 80 parts, tin solution

* This colour, the most celebrated, and brought to the greatest perfection among the ancients, was accidentally discovered about 1,735 years before the Christian era. Poetry has wrapped her embellishments around the facts, which appear to be these: One of the shepherd kings of Phœnicia, whom some name the Tyrian Hercules, was traversing the strand, accompanied by his dog, which was incited by hunger to devour some shell-fish. The mouth became stained of a beautiful colour by the liquid; and the owner's attention being excited, this led to trials of the effect on woollen fabrics, and the success surpassed all his expectations. His devotedness to the interests of his country, equal to that of a lover to his fair one, caused him to restrict its use, on pain of death, as symbols of power and of office, only to the chief priesthood and royalty; and he employed every effort to secure the revenue to his own city, and preclude depreciation of the article. I need not more than just hint at the great oversight of persons who give the person and date, Phœnix, *second* king of Tyre, 500 B.C., when Hiram was king more than 1000 years B.C. The black, yellow, blue and green colours Alexander the Great brought from India.

(2) 20, and silver solution 1 part, add of pure water, at 200° Fahrenheit, 800, 200, and 10 parts respectively. First mix well the solutions of gold and silver; over the liquid with a feather sprinkle a solution of caustic potash, which at intervals repeat cautiously, else peroxide of tin will be formed; then stir very carefully with a strong feather the liquid while pouring in the solution of tin, and while any precipitate appears continue adding pure boiling water, and let the whole repose forty-eight hours. To brighten the tint, wash the purple in dilute nitric acid, and a portion of the tin will be solicited, and can be filtered out. The precipitate 25 parts with 75 of flux 10; or 20 parts with 80 of flux 8; or 18 parts with 88 of flux 14; or 20 parts with 10 white oxide of antimony and 78 of flux 10.

Another formula is—gold solution 47, tin solution 47, silver solution 6; and the precipitate 25 parts with 75 of flux 4.

Purple Distance.—The gold precipitate 22, 36, very clean oxide of manganese 15, 18, and 63, 46, of flux 10.

Unnumbered have been the failures in the preparation of this beautiful colour, and very probably because of the difference of opinion with reference to its chemical components. One of the first authorities of the age, Dr. Thomson, considers that it is formed "by dropping a solution of gold into a solution containing *both the oxides of tin.* When dropped into a solution of protomuriate of tin, it is a dark brown, without any beauty. We must have both oxides in the solution to ensure the fine purple of Cassius." Now, I beg to remark, that here appears a complete

oversight of the complete difference between precipitating tin by gold and gold by tin. The doctor also says: "It has been supposed that this beautiful colour is owing to the presence of an oxide, between the *sub* and *per* oxides, of whose existence no satisfactory evidence has been adduced. But the observations of Proust, together with those of Marcadiew (*Ann. de Chimie*, etc., XXXIV., 147), seem to leave no doubt that the gold in this beautiful powder is in the metallic state." Even if this be the fact, does it remain so in the tints it supplies to glaze and enamel? And is not this supposition of the combination of metallic gold with the peroxide of tin contrary to every known analogy of the combination of metals with oxides? There is great probability in the following opinion: One oxide of gold, g. 1 + 1 ox., always forms green or yellow combinations, and has present only one-third the supply of oxygen in the other, g. 1 + 3 ox., which forms the rose-colour. Now, as opposite tints result from these two states of oxidation, the opinion is induced that for the forming of the purple it needs a less degree of oxidation of the gold than the rose-colour; the deutoxide, because not salifiable, is not discovered, as are the others, and yet it will with the oxide of tin form a compound, solicited by ammonia to solubility, proving it an oxide. The purple needs this deutoxide, and cannot exist without it, and the numerous failures have been from attempting this with the other two oxides. In fact, as Berzelius says: "The oxides g. 1 + ox. and g. 1 + 3 ox. combine with acids, while the oxide g. + 2 ox. does not combine with other bodies, though it has an affinity with other oxides."

The tin solution (1) has the metal in the state of per-muriate, from whose employment in forming the purple have resulted numerous disastrous, vexatious, and most expensive failures in the processes, and when the ware was baked. The solution (2) or (3) contains the tin in proto-muriate, regarded as *that only* proper to be a component of the potter's purple. If Dr. Thomson be correct, then certain proportions of each must be used for the purpose.

An opinion is current, that by mixing the very dilute solutions mentioned, every *two* parts of gold will supply *eleven* of purple. The quantity of solvent it will appropriate proves the colouring power of the purple, compared with flint-glass, as 1000 to 1 ; and as 12 to 1 is that of the oxide used in the carmine to the purple. Other different preparations of gold, without the presence of an atom of tin, will supply a fine purple ; proving the tin not essential or indispensable to purple enamel colour, as it has very slight colouring power, therefore does not add to the basis of the colour. Its precise use is its peculiar property of adapting the purple, of which it is an ingredient, to retain its indispensable dose of oxygen, while sustaining the duration of a higher temperature of the baking process, requisite to be appropriated by the glaze ; it also renders the gold refractory at a very high temperature, while the solvent preserves the proper state of oxidation. The purple is most advantageously applied to a surface whose vitrification dissolves the oxide as quickly as it is formed, precluding the reduction, and the purple continues firm until dissolved by very high temperature. Upon the perfect manner of performing the processes of enamelling, mainly depends the

beauty of the manufactured article; any irregularity causing pain to the experienced eye, and much liability to greater injury attaching to the endeavour to correct it.

As far as colours and materials are proper, we possess the requisites for ensuring, to productions of the pencil, whatever degree of immortality they deserve. And had the philosopher Davy only recollected this fact, as referring to our best porcelain, he would have qualified the expression used by him when in Italy: "It is unfortunate that the materials for receiving those works which are worthy of passing down to posterity, as eternal monuments of genius, taste and industry, are not imperishable marble or stone." What are these when compared with the hard porcelain? And even the soft kinds will long remain uninjured by extraneous atmospheric action.

When the purple powder 16 parts have 84 of flux 18, a very beautiful VIOLET is produced by the peculiar action of the lead present.

OTHER PURPLES.—For flint ware, frit together well-pulverised oxide of manganese 44, 48 parts, zaffres 5, 8, red lead 51, 44; *Lilac*, manganese 38, smalts 62.

Another Aqua Regia.—When chromic acid and muriatic acid are distilled by a gentle heat, chlorine is produced; and a chemical mixture of chromic and muriatic acids forms an *aqua regia* which will dissolve gold. This potency, not possessed by any other of the metallic acids, is supposed to be consequent on the slight re-action of oxygen on the base.

Reds, etc., *obtained from Iron.*

The temperature to which oxide of iron is first raised will cause the tint to be *Rose-Red*, or *Brown*, of different shades; yet, when properly prepared, unchangeable on soft or hard porcelain. This rose-red has been long known; but either because when first the painters on enamel commenced their labours on porcelain they neglected to adapt their methods to the different recipient, or because they feared it would be evanescent like the carmine, it was not used with the advantage of which it is susceptible. Though it may be diminished in brilliance compared with the carmine supplied by the oxide of gold, yet on a good glaze of felspar, natural or artificial, it is changeless, preserving a tint peculiarly fine and rich; and combined with the proper flux, No. 22, substituting minium for flint, it is certain in application, and with it roses have been frequently painted, which only improved in brilliance by the baking. The beauty of tint is supposed to result from imperfect vitrification, which causes or allows the particles of the peroxide to be in an extremely comminute state suspended in the solvent or flux.

When the glaze has excess of oxide of lead (as soft porcelain), there ensues a volatilisation of the oxide of iron, by which its clearness is affected to a dull disagreeable brick-red, as likewise from minus of flux, or higher temperature. To supersede this liability to change, a saturated solution of sulphate of iron has alumine mixed carefully with it, and afterwards test 3 is added until precipitation ceases.

I have already noticed (p. 489) the potency, as in this instance, with which alumine solicits oxides.

1. In nitric acid 66 parts and pure water 34, dissolve clean iron-filings; dilute the liquid, and add test 4 till precipitation ceases. This place on a sheet of iron, and by a bright fire bring to a fine bright *red*. *Colour*, precipitate 30 parts and 70 of flux 9. 2. The precipitate (1) 34 parts mix with 66 of roasted table-salt, which incandesce; then mix well in boiling water in great excess, and let it repose forty-eight hours; by siphon abstract the water, throw the sediment on a filter, and wash well with pure boiling water. For *Rose*-colour, precipitate 25 parts with 75 of flux 9. 3. In a bright open fire calcine good sulphate of iron till there remains the fine orange, or bright red peroxide of iron (not at a very high temperature, else it will be brown, or cream-white); wash well in plenty of boiling pure water to abstract the sulphuric acid, then on bibulous paper dry the powder. For *Colour.—Enamel Reds*, calc 25, 30, with 75, 70 of flux 9. *Light*, calc 40 and 60 of flux 8. *Brown*, calc 15, 20 parts with 85, 80 of flux 22. *Flesh*, perchloride of manganese (supplied by saturating muriatic acid at 1·149 with black ozide of manganese, diluting with ten bulks of pure boiling water, filtering, concentrating, and leaving to repose for crystallisation), when dried and ground, use in equal quantities with flux 22. Another is formed by a very dense solution, long evaporated, of clean sulphate of iron 28 oz., and 8 oz. of gum Arabic kept close in a phial. *Pink*, mix and frit 12 to 18 hours oxides of chrome 35, 40, 45, of tin 40, 35, 30 with lime 25. It is a compound of chromic acid 2, peroxide of tin 1, and lime 1 = 25·75. *Dark Brown*, brown oxide of iron 34 with 66 of flux 22. *Light Brown*, calc of enamel red 12, calcined umber 9, chrome yellow 9, with 70 of flux 7. A small portion of oxide of iron raised to a very high temperature to fully vitrify it with a large proportion of flux or solvent supplies different shades of *green* to *yellow*. A larger dose of oxide supplies a *yellow* by full vitrification; and a yet larger dose a *brownish-black*, that seems a very dense or contracted yellow, as this tint results again from it by diluting the previous dark colour with much of the solvent. The mixture of varied proportions of the red and black oxides of iron will supply the different shades of *red*, *brown*, *chocolate*, *chestnut*, etc.

Brown-Reds and Bistres are supplied from the mixture of varied proportions of the black oxide of manganese, brown oxide of iron, and oxide of chrome, fritted with the components well determined, and a certain quantity of the flux or solvent, and then properly ground. This mode of preparing the brown-reds prevents any change in the tint by baking, whether used on soft or hard porcelain, the oxide of manganese promoting the fusibility of the iron into its yellow oxide, and counteracting the potency of the lead in the glaze to destroy the tint of the iron, already noticed. (See p. 499, *note.*)

Red-brown. Frit two hours peroxide of manganese 67, 75, brown oxide of iron 13, 15, oxide of chrome 20, 10; then colour 50 with 50 of frit 8, fuse other two hours. *Brown* for biscuit. Frit two hours oxide of manganese 56, 60, 65, brown oxide of iron 24, 20, 20, oxide of chrome 20, 20, 15; then of colour 35, 44, 56, with 65, 56, 44 of flux 7, fuse other two hours. *Mulberry*, for biscuit. Brown 95, 92, 90, zaffres 5, 8, 10, grind well for use. For *Grounds.* Brown-red, russet, and tortoise-shell. Mix brown-red colour 30 with 70 of flux 10; 36 with 64 of flux 7; 35 with 65 of flux 20.

Whenever bitartrate of potass or tartar is introduced as a component of certain colours, considerable care is needful, because the escape of the carbonic acid gas creates a very violent effervescence, which may carry into the fire some of the metallic oxide, the base of the colour, and occasion a proportionate loss of metal, and consequent weakness of tint. Some persons substitute fresh burned and well-dried charcoal, incandesced in a covered crucible, and then added to the frit. A remedy for the effervescence seems offered in the practice of the bottle-glass makers: Cast in a little water, this will decompose; its oxygen will combine with the carbon, and as carbonic acid gas it will be dissipated by the intense heat; the frit will continue sluggish until the whole process is finished.

BLUES.

It is well known that cobalt supplies the best test of the presence of alumine in an assay. We therefore need not be surprised, but might naturally expect, that preparations of oxide of cobalt would supply blue tints to a silicate of alumine, more rich, solid, fine, and fixed, whatever might be the degree of temperature to which the baking is raised; and the Manufacture of porcelain and flint wares established the supposition. Certainly the components of the wares, body as well as glaze, will affect the tint, however excellent the colorific oxide; but mostly the varied shades and gradations of excellence are caused by the presence of ingredients introduced from motives of cupidity. Whenever the lines of the design are smeared, instead of being clear and distinct, there is great probability that the presence of arsenic acid has caused the volatilisation of the cobalt at a heat lower than would have been requisite had it been pure oxide.

In obtaining the oxide, each *blue-maker* follows his own processes, usually some modification, according to circumstances, of the following :—

Take cobalt metal 45 parts, carbonate of potash 45, charcoal 6, Lynn sand 4; or 40, 40, 6, 14; or 50, 40, 5, 5. Mix well, and with it half-fill skittle-shaped crucibles; place these in a muffle, or a reverberatory furnace, gradually raise the heat five hours, keep the temperature steady three hours longer, and gradually diminish for eight hours. When cool, the upper stratum in each crucible is cobalt oxide with a silicate of potash; the lower is an alloy of nickel and bismuth. Pulverise the silicate and mix 90 parts with 10 of potash. Of this mixture, into a pint flint-ware

biscuit-flanched jar, put 1 pound; raise the temperature four hours, keep it steady three hours, and lower it gradually six hours more. This process must be repeated until the colour seems very pale. Pulverise the calc; and to dissipate any arsenic present, which fusion will not, on a layer of dry flint-powder spread the calc, and calcine during six hours, which will also separate the nickel. Some persons next mix cobalt 90, flint 6, and borax 4; others mix 85, 9, and 6 of potash.

Mix equal weights of zaffre and potash, which put into cups 3 inches diameter, $1\frac{1}{2}$ high, and $\frac{1}{2}$ thick; place in the muffle, raise the temperature as last directed. The upper stratum will be blue calc, the lower nickel and scoria. The nickel, when a sufficient quantity is accumulated, is pulverised, and to the metal 80 parts, add plaster 12, potash or borax 8, and in strong cups fuse at a high temperature during 16 hours.

For the colour, *strong*, cobalt 40, 35, 30, 25, 20, with 60, 65, 70, 75, 80 of flux 7, or 13; *weak*, cobalt 25, 20, 15, with 75, 80, 85 of flux 22. For *painting*, cobalt 25, 20, 30, with 75, 80, 70 of flux 8, or 14. MATT-BLUE, cobalt oxide 60, zinc 15, lime 25, or 65, 15, 20; for use, mix colour 35 with 65 of flux 22.

The following has been forwarded by an anonymous correspondent, who thinks it entitled to attention, as *Westrumb*, from whom it is stated to be copied, is of admitted celebrity: By some convenient method carbonise animal oil, to which add soda or potash, and incandesce for 30 minutes; then mix this, as 25, 30 or 35 parts with 8, 12, or 16 of alum, and 67, 58, 49 of sulphate of iron, which frit two hours; and when cool, take of frit 40 parts and mix with 60 of this solvent (frit), well-dried sulphate of soda 50 parts, Lynn sand 35, and 15 of charcoal powder. The statement suggests this as an approach to the *blue* employed by the ancients on their beads, on whose peculiar processes no record is known to remain. Brongniart says: "The pure chromate of lead, on porcelain very highly baked, supplies a very deep and fixed blue of considerable beauty." And, according to Kuhlman, the like result is obtained from calcining sulphate of soda 12 hours in a reverberatory furnace. Another process is: *Ultramarine.*—Carefully mix china clay 25 parts, flowers of sulphur 37, and pure dry sub-carbonate of soda 38; in a coated porcelain retort raise the temperature gradually until all vapour ceases to escape; the spongy result at first reflects a green tint which the action of the

atmosphere changes into blue; pulverise, and wash out all the sulphur possible, decant the liquid, dry the powder, calcine to a cherry red, to dissipate the sulphur, and the remainder is a good blue, though not very intense. The mixture of saturated solutions of cobalt and alum, precipitated by test 1 or 3, also those of carbonates of zinc and iron saturated with cyanogen gas (from cyanodide of mercury), and precipitated by test 4, will produce fine *Blues*, but some attention is needful in the baking.

"A print is the translation of a picture, legible to every eye, and current in every country; distributing the admirable productions of Art into the hands of thousands, who, but for engraving, must have lived and died in ignorance of their worth, because unacquainted with their merits."

The discovery of printing from plates of metal is assigned to a goldsmith of Florence, named THOMAS FINIGUERA, about the middle of the fifteenth century. This ingenious man, having finished some ornamental work in which engraving was employed, and having filled the strokes with a black substance to render them conspicuous, while examining the effect produced accidentally let fall on it some of the melted wax of the taper which lighted him. This quickly hardened on the cold metal, and when chipped off its interior surface was observed to present a correct transcript of that part of the engraving on which it previously had fallen. This suggested to Finiguera the idea of obtaining by some method, impressions of engravings on paper, and he was not long in successfully realising the object of his research.

YELLOWS.

YELLOWS, as much as any of the other colours, are improved in quality and permanence by the methods of preparation suggested by the improvements in chemical processes. When the quantity of oxide of lead present in the colour, and also in the glaze, was so great that seldom could the most careful mixture of other ingredients and management of the processes prevent a portion being de-oxidated, and appearing in black specks on the glaze, the tints of the oxides of iron were so affected also by the oxygen evolving, as frequently to present, after baking, merely a faint outline, instead of a well-defined figure. The substitution of chromic acid for carbonic increases both the brilliance and permanence of the tint; while the introduction of the natural or artificial felspar glaze, because of its alkaline properties, has facilitated its application. None of the ancient yellows was so durable, brilliant, and beautiful as this *chrome yellow;* superior to preparations of oxides only, as this insoluble salt, resulting from chemically combining a metallic acid with a metallic oxide.

Upon glazed flat dishes expose iron filings sprinkled with water, to be oxidated by the action of the atmosphere. After 24 hours, constantly, wash off the oxide into a foot-bath well-glazed. The water draw off by siphon, and again use to wash off the oxide. When the oxide is needed, let the repose be 48 hours, then draw off the water, as before, and on bibulous paper dry the precipitate; then put it into a crucible, cover close up, and incandesce 4 hours for a bright tint, and 6 to 8 for one darker. For use, colour 35, chrome yellow 10, and 55 of flux 12. *Chrome yellow.*—To dilute solution of nitrate of lead, add solution of chromate of potash until

precipitation ceases; then leave to repose 48 hours, by siphon decant the water, and dry the precipitate. Or, saturate a pint of pure water by acetate of lead, and add 16 oz. of carbonate of barytes; boil, and stir in half an ounce of chromate of potash; after 24 hours' repose decant the water, and dry the colour for use. Frit for 2 hours chromate of iron 70, pearlash 30, or 80, and nitrate of potash 20; add water, and keep at 212° till all the frit is in solution; then add solution of acetate, or nitrate of lead; repose 24 hours, then filter for use. *Nasturtium.*—Iron precipitate 10, chrome yellow 20 parts with 70 of flux 10. *Orange*, biscuit.—Frit 3 hours brown oxide of iron 26, 30, 35, antimony 74, 70, 65, and about 4 of tin ash. Colour 40 with 60 of flux 1, 2, or 3. For Enamel, substitute the red for the brown oxide of iron. *Base yellow.*—Frit 3 hours antimony 17, 10, 36, 10, litharge 17, 10, 48, 15, tin ash 33, 40, 16, 45, lead ash (or white lead) 33, 40, 0, 30.—Frit minium 80, sal ammoniac 20.

The minium or red oxide of lead is mostly employed by the colour-maker, because scarcely can it be adulterated; and next in genuine quality is litharge, the brown oxide; whereas the other, the *white* oxide, is readily mixed with *Dutch lead*, sulphate of barytes, the detection of which requires careful analytical processes. Unless the materials be genuine, there will result considerable loss. And even when they are, the most sedulous attention to the rise and duration of temperature, as well as the precise proportions of components, are indispensable. Hence the advantages possessed by a person with adequate capital, who, preparing a large quantity of the colour, secures the peculiar tint for his customers. Was the test of difficulty the unsuccessful attempts to excel in this department, we might conclude that the enamel purple, and printing pink, red, brown, and green, are among the most rare productions, which require all the skill and judgment of practice, with the investigations of science.

GREENS.

THE colours with this tint now generally accepted, are preparations of chrome, which without injury sustains any temperature to which it may be requisite to raise the ware. Their preparation also is less liable to mutability than those from oxide of copper, or from mixture of yellow and blue, which need fritting with their solvent or flux before grinding to capacitate them to bear high temperature, without the tint becoming black.

Green Oxide of Chrome.—Slowly raise to a state of incandescence a mixture of chromate of lead and oil, and when metallic globules appear, quickly raise the temperature much higher; leave the crucible to gradually cool; the upper stratum will be green oxide, the lower the lead in its reduced state. Colour 40 with 60 of flux 23. Another process is—mix saturated solutions of chromate of potash and nitrate of mercury. The reciprocal potencies of the substances combine to form fresh compounds, chromate of mercury and nitrate of potash. This latter is washed out of the filtered precipitate by boiling pure water; the powder is then brought to a very high temperature of 500° to volatilise the mercury, cause part of the oxygen to evolve, and leave the pure green oxide. Colour 35 with 65 of flux 21. Boil a saturated solution of chromate of potash, to which add alcohol 12, and sulphuric acid 13, per cent.; repose 12 hours, filter out and incandesce the beautiful green hydrate of chromium. The solution of chromate of potash, at 120° Fahrenheit, carefully treat with either test 2, or 7; the former let repose 24 hours, and filter out; the latter evaporate dry, for use. A saturated solution of a muriate, acetate, or arsenite of copper, treat with a solution of carbonate of potash; and when the precipitate becomes sluggish, let it fall into a separate vessel. The tint obtained from the latter is olive, dull, and dense; that from the former is brilliant and clear. The shades vary because of the acid present with the salt. The fluxes are Nos. 3, 4, 5. *Emerald.*—Frit oxide of chrome 50, oxide of nickel 35, nitre 15. Colour, frit 35 with 65 of flux 9.

Brongniart says, "oxide of nickel 80 and nitre 20 parts supplies the emerald green of the Sévres porcelain, and uninjured will bear any degree of heat." *Olive.*—Frit oxide of nickel 65, zaffre 35. Or, chromate of lead 80, potash 15, arsenic 5. Colour, equal weights of frit and flux 12. *Celeste.*—Frit 2 hours chromate of lead 35, 42, 49; oxide of zinc, 5, 7, 10; zaffres 40, 51, 41. Most brilliant on a glaze of artificial felspar, on soft porcelain. *Blue.*—Frit 3 hours brown oxide of copper 65, 72; yellow oxide of iron 35, 28. Colour, frit 35 with 65 of flux 20.

Mineral Greens.—Dissolve to saturation sulphate of copper in hot water, and while hot add saturated solution of carbonate of potash; also carbonate of soda, sulphate of magnesia, sulphate of iron or potash, sulphate of alumine, and the two last precipitate with bi-carbonate of potash. The precipitated basic carbonate of copper filter and wash, then dry.

In a solution of potash boil white arsenic, and this arseniate of potash, added to a solution of sulphate of copper, produces a green precipitate of arseniate of copper; filter, wash with pure cold water, and dry. *Scheele's Green.*—Filtering each solution prior to mixture greatly improves the resulting colour. Also adding 15 per cent. of acetic acid, and instantly throwing the liquid on the filter, will supply a different yet very beautiful green.

Vienna Green.—In pure vinegar, heated in a copper vessel, dissolve verdigris to saturation; then add solution of white arsenic an equal quanity; add vinegar till all the precipitate is re-dissolved; distil till a fine green crystalline precipitate falls; filter, wash, and dry for use. When copper remains, add more arsenic; when arsenic, add more copper, till the mother-liquor is rendered inert. Prior to distillation, adding 10 per cent. of potash or of lime, carbonated, will much alter the resulting colour.

BLACKS.

Blacks of the greatest beauty and brilliance are now supplied in lieu of those which had been troublesome and uncertain. But as no metallic oxide, *per se*, supplies a black sufficiently dense for porcelain—platinum best, manganese next, while that of iron fails, blisters, is dull, opaque, and easily becomes reddish, and as lead glazes caused the enamel blacks to scale off, or lose their brilliance—the general practice is current of chemically combining (not merely mixing) several oxides, as manganese, cobalt, nickel, iron, and chromium, which supply a brilliant colour for alkaline glazes. I have already remarked that the components of the biscuit often much affect the colours. In blacks this is very obvious.

Frit 2 hours black oxides of manganese 38, of iron 36, zaffres 26. Colour 45 with 55 of flux 22. This is the *black* of the Sévres porcelain. Frit black oxide of manganese 40, 50, 50, oxides of chromium 10, 12, 15, of iron 8, 12, 15, of nickel 10, 6, 2, and zaffre 32, 20, 18 ; the combinative potencies of the manganese and cobalt are remarkably obvious when fritted together ; for, as with alumine, complete combination ensues, and the result is a deep black. Colour, equal weights of frit and flux 23. For enamel.—Frit 2 hours manganese 32, 30, zaffre 16, 20, brown oxide of iron 24, 20, nickel 2, 4, oxide of chromium 8, 10, copper 12, 14, nitre 4, 0.

General Black Flux.—Ignite nitrate of potash 1, bi-tartrate of potash 2.

PURE WHITE.

THE preparation requires operose processes to secure a clear tint, with a body sufficiently fusible to readily bake with any glaze. Also the precise proportions of the components require to be accurately stated.

In pure water at 120° dissolve 16 oz. of good table-salt, filter, evaporate partially, and crystallise for the square crystals, or dry and decrepitate the salt. Into a red-hot crucible put a determined weight of grain tin, and when fused, add twice the weight of the salt, or thrice of the crystals; closely cover, often stir with a red-hot spatula, and when it is of a white heat, keep the temperature up 80 to 90 minutes; cool, pick, pulverise, and raise the temperature during 3 hours; cool, pulverise, with great excess of boiling water wash out all the salt, let both repose 24 hours, then by siphon draw off the water, and dry the precipitate for use. Another.—Kunkel, Neri, and some others, direct to frit tin 55 with red lead 45; then for 10 hours alloy 58, flint 58, tartrate of potash 4. Again, frit for 3 hours calc 80, with 20 black oxide of manganese; pulverise, wash well in cold water, and repeat the process of calc and manganese until the residuum becomes fine and perfectly white.

General White Fluxes.—Into a red-hot crucible project:—

1.—Nitrate of potash 1, and bi-tartrate of potash 1.
2.—Dried common-salt 4, dry lime 4, fluate of lime 2, charcoal 1.
3.—Calcined borax 40, lime 4, charcoal 5.
4.—Glass powder 4, borax 2, charcoal 1.

Silver *for Egyptian, or to Burnish.*

By polished copperplate immersed 24 hours precipitate silver from a dilute nitric solution; filter, wash well, dry, and to silver 80 add 20 of good ceruse. By clean iron filings precipitate the copper for a rich *bronze.* Another—As silver is affected by vapours, black when sulphur is present, and tarnished by the atmosphere, cannot be used in extreme comminution, nor traced very fine and thin, Klaproth suggests a substitute in platinum, free from any of these inconveniences. In *aqua regia* 2 dissolve platinum, add test 34, filter, wash well, evaporate dry, and incandesce, to dissipate the precipitant; to the powder 35 add 65 of flux 23; use with oil of spike, bake and burnish. When platinum 35 with 65 of gold are used, the silvery brilliance on a convex surface covered thrice, and carefully baked, excels that of a polished steel mirror.

Gold *for Burnishing.*

There is requisite much care and attention, because great difficulties often occur in not properly managing the gold in these processes, to provide antidotes against its deoxidation by sulphuretted hydrogen, carbonaceous vapours, or extreme rise of temperature ; and yet secure that comminution of its particles that peculiarly adapts it, with a certain proportion of solvent or flux, for economical application to the glaze with which it is required to combine.

Mix solutions of gold 75 and 25 of silver, to which add 900 of pure water at 212°. Carefully stir while adding a saturated solution of proto-sulphate of iron, till precipitation ceases ; add a little, and let it repose 24 to 48 hours ; by siphon draw off the water, wash well, dry on bibulous paper, and mix borax at pleasure for use. Or, mix solution of gold 77 with 33 of silicate of potash ; add test 26, till precipitation ceases ; allow repose, filter, wash, dry, and use metal 10, flux 90. Or, the solution of gold evaporate dry, wash well in excess of pure water, raise the temperature to 130°, add test 1 till precipitation ceases, and let the orange precipitate repose not less than 24 hours ; by siphon draw off the water, evaporate the precipitate, and add flux as needful. Were the process reversed, the aciduline potency of the gold would with the alkali form a blackish-brown result. Or, alloy gold 80 with oxides of silver 13 and 7 of bismuth ; or gold 66 with 34 of mercury. Alloy 26, 30, to 74, 70 of black flux (33 nitre, 67 bi-tartrate of potash).

PRINTERS' OIL.

Boil during 2 hours linseed-oil, very carefully removing whatever scum may be thrown up; add red lead, and burn off all greasy particles; other ingredients add as stated, to preclude coagulation; simmer 2 hours, and cool for use. The proportions vary with different persons.

1. Oil 1 quart, red lead ½ oz., oil of amber 1 oz., capivi balsam 1 oz., oil of turpentine 1 oz., Stockholm tar 1 oz., Barbadoes tar 1 oz. 2. Substitute Venice turpentine 4 oz., and oil of amber 4 oz. for the oil of turpentine. 3. Linseed-oil 1 pint, Stockholm tar ½ pint, rosin 2 oz. 4. Oil 1 quart, tar 2 oz., balsam of sulphur 2 oz., Venice turpentine 1 oz. 5. Oil 1 quart, rape-oil 1 pint, (or ¼), capivi balsam 2 oz. (or 1), pitch 1 oz., amber oil ½ oz., ceruse ½ oz. (or tar ½ oz., balsam of sulphur 1 oz.). 6. Linseed-oil 1 quart, flowers of sulphur 4 oz., balsam of sulphur 4 oz., rosin 2 oz. 7. Linseed oil 1 quart, red lead 2 oz., balsam of sulphur and Barbadoes tar, of each 4 oz., and ½ an oz. each of capivi balsam, oil of amber, acetate of lead and rosin.

LUSTRES.

Gold.—In an earthen jug put balsam of sulphur (oil of turpentine 86, flowers of sulphur 14 parts), then raise the temperature to 200, and continue 60 to 80 minutes. When cool, add by measure, to every 60 parts, 40 more of oil. Over a slow fire again raise the temperature, and carefully stir therein 95 per cent. of the gold solution, and 5 per cent of the tin solution. This gives the purplish tint to the gold lustre. *Solid Gold Lustre.*—On a well-glazed plate with *fat* oil mix up a certain weight of the gold precipitate (see p. 506—7); raise the temperature till the oil is fluid, then add oil 25 parts, reduce the temperature and add turpentine 75 parts.

New Lustre.—The process is—With gold lustre first form the pattern and bake the ware; next take gold solution, and with a feather cover the pattern; this last cover with a saturated solution of sulphate of iron, which precipitates the metallic gold on the pattern; wash well in water, and bake at about 600° Fahrenheit—the fusing point of lead.

Silver.—This lustre is prepared by a process much different. Dissolve good platinum in *aqua regia* at a raised temperature; gradually add to this solution thrice its quantity of spirits of tar, and avoid the gas which evolves while the acids are being dissipated. The platinum remains in the fluid; and, for use, this is evaporated to proper consistence.

The glaze for silver lustre usually has much oxide of tin present with the other materials, from the combinative potency with the oxide of platinum tending to improve the clear bright metallic tint of the lustre.

How Nature should have proceeded in a certain mode of combination for substances and for colours, agreeably to determined laws which human research has developed, and from which she never departs, can be adequately explained solely by the admission of a "GREAT DIRECTING MIND!"

Whatever contributes to the beauty of another object to a certain extent partakes of that beauty; because the relative forms, and the particular conformity, reciprocate the beauties, although one may be negative, or even uncomely. In the employment of her colours, Nature is lively by contrast solely, and by the judicious arrangement displayed; their opposition manifests her operations, and communicates to the results life, fire and the greatest *éclat*. Most of the tints she uses are composed of many colours and shades, and seldom can we find in flowers, shells, or animals, colours of only two components. Seldom, also, is a fine tint left without being contrasted by one obscure; and these latter, in most instances, become interesting by this contrast to colours truly rich, and with which those obscure are thus assorted. Yet with what inimitable skill does she accomplish this contrast of her tints, and the proportion of her lights and shades; and the nearer the approach to these by the imitations of our artists, the greater will be the excellence of their productions; whether to delineate the different dyes of fruits in our gardens, the varied hues in our plantations, and the diversified shades in our fields; whether to attempt a resemblance of the velvet white of the lily, the delicious purple of the violet, the rich crimson of the amaranth, or the glowing blushes of the rose.

Kunckel gives these as the *true* components of the colours used in the 17th century at the Delft and other Dutch Manufactories, which doubtless have suggested many useful hints to subsequent Manufacturers:—

Black—red-lead 50, iron-filings 19, copper-ashes, *æs ustum* 19, zaffre 12.

Blue—frit thrice, and throw cool into water—red-lead or lead-ashes 14 (Lynn) sand or dry flint-powder 30, common salt 28, white calcined tartar 14, cullet 7, zaffre 7; the duration of the final fritting determines the fineness of the tint (K. says 2 days).

Or—tartar 65, red-lead 17, dry flint 16, zaffre 2.

Or—tin-ashes 6, lead-ashes 6, tartar 6, cullet 6, zaffre 10, dry flint 33, salt 33.

Or—red-lead 20, zaffre 20, sand 60.

Violet—tartar 35, red-lead 18, dry flint 45, manganese 2.

Brown—frit—red-lead 7, dry flint 7, manganese 1.

Or—red-lead 92, manganese 8.

Or—(for a white ground) twice—manganese 50, red-lead 25, cullet 25.

Flesh-colour—lead-ashes 92, cullet 8.

Gold colour—frit—litharge 75, sand or dry flint 25, grind fine, dry, with nitrate of silver form a paste; in a crucible gently raise the temperature and form a green glass; grind with beer and apply to the well-heated ware; in the muffle cause the glaze to flow (and, says Heinsius, *afflare debes fumum*), let them cool amidst the vapour of burning vegetables (*Phil. Trans.* 465, Sect. 6).

Or—(five times)—saffron of Mars 1, red-lead 3, antimony 2.

Or—red-lead 40, antimony 40, iron-scales 20.

Or—red-lead 48, flint 36, yellow ochre 6, antimony 6, cullet 4.

Or—(transparent) twice—red-lead 48, dry flint 48, iron filings 4.

Green—frit—litharge or red-lead 40, cullet 40, brass or copper-filings 20.

Or—litharge 45, flint 50, copper-ashes 5.

Or—(fine) Bohemian fluor spar 25, copper-filings 25, red-lead 25, cullet 25.

Or—frit the other components, and grind with half the weights of Bohemian fluor.

Sea-green—frit—lead-ashes 48, tin-ashes 10, flint 26, salt 7, tartar 4, copper-dust 5.

Iron—ditto—lead or red-lead 44, sand or flint 44, copper calc 12.

Liver—ditto—litharge 48, salt 24, flint 24, manganese 4.

Purple-brown—frit—lead-ashes 30 (or red-lead), sand or flint 36, manganese 3, cullet 30, zaffre 1.

Red—frit—litharge or red-lead 43, antimony 43, iron-rust 14.

Or—red-lead 50, antimony 32, saffron of Mars 18.

Yellow—frit four times—red-lead 43, glass of antimony 29, tin-ashes 28 (or 33, 33, 34).

Or—lead-ore 45, litharge of silver 10, sand 45.

Or—(fine)—red-lead 45, brick-dust 18, sand 9, white-glaze 9, antimony 19.

Or—cullet 44, antimony 11, red-lead 33, iron-scales 12.

Or—litharge 65, flint 30, iron-filings 5.

Or—(light) red-lead 56, antimony 16, cullet 16, tin-ashes 12.

Or—(citron, in a glass-furnace, 108 hours), red-lead 40, antimony 13, red-brick-dust 47.

White-glaze—frit thrice—litharge or lead-ashes 50, sand 29, salt 10, ashes 15.

Or—sand 30, lead-ashes 45, wood-ashes 19, salt 6.

Or—lead 66, tin 34. These frit, lead and tin-ashes 50, flint 25 (or sand or cullet), salt 25, or 34, 33, 33.

Or—(fine) five times—red-lead 75, tin-ashes or putty-powder 16, salt 9, or litharge 68, tin-ashes 23, salt 9.

All simple or compound colours, and all the tints produced by Nature or Art, proper for the different kinds of printing, form an extensive catalogue, regarded only by certain external characters, or their intensity. However Art, directed by the experience of centuries, prescribes bounds to the consumption of colorific substances, by their limitation to bright, splendid, durable tints. The following NOMENCLATURE OF COLOURS, for the primary and compound tints, has been attempted, with reference first to the Colours of Minerals least evanescent, and next to those of common well-known plants :—

1. *Æruginosus*—Æruginous, bluish-green, like verdigris, and some pine-tree leaves.

2. *Albidus*—Sand stone colour.

3. *Albus*—White, chalk-white, *cretaceus*—snow-white, *niveus*—milk-white, *lacteus*.

4. *Altrovirens*—Dark green.*

5. *Ater*—Deepest black, brown-black, *piceus*.

6. *Atropurpureus*—Very dark reddish-purple, as in the *Scabiosa atropurpurea*.

7. *Atrorubeus*—Dark-red, as in the *Amaranthus hypochondriacus*.†

8. *Aurantiacus*—Orange colour, as the flowers of the *Marigold* and *Nasturtium*.

9. *Aureus*—Golden yellow, as that of *Sunflower* and *Dandelion*.

10. *Azareus*—Azure blue, like ultramarine ; colour brighter than the *Cæruleus;* like the pure light-blue flowers of the *Cynoglossum omphalodes*.

11. *Badius*—Browner than liver colour.

12. *Brunneus*—A deep dark-brown.‡

13. *Cæsius*—A dull light-blue grey.

14. *Castaneus*—Chestnut, russet or orange-brown.

15. *Carneus*—A flesh colour, as the pale blossom of the *Thysperis matronalis*.

16. *Cinereus*—Ash colour.

17. *Cinnabarinus*—Like red lead or cinnabar; and the gay red of the Oriental Poppy, *Papaver Orientalis*.

18. *Coccineus*—High crimson, or bright scarlet ; as the flower of the *Salvia Coccinea*.

19. *Cæruleus*—Sky-blue, *cælestinus*, like the flower of Borage, and the

* Green *viridis*, blue-green *glaucus*, light copper-green *malachiticus*, copper-green *æruginosus*, sea-green *thalassinus*, black-green *atroviridis*, olive-green *olivaceus*, pistachio-green *pistacinus*, dark-green *prusinus*, s. *obscurè viridis*, yellow-green *luteo viridis*.

† Red *ruber*, blood-red *sanguineus*, fire-red *igneus*, scarlet-red *coccineus*, crimson-red *chermesinus*, carmine *puniceus*, tile-red *lateritius*, yellow-red *fulvus*, light yellow-red *testaceus*, s. *clarè fulvus*, flesh-red *carneus*, light flesh-red *incarnatus*, s. *pallidè carneus*, rose-red *roseus*.

‡ Brown *brunneus*, red-brown *rufus*, rust-brown *ferrugineus*, light rust-brown *cinnamomeus* s. *clarè ferrigineus*, chestnut-brown *castaneus*, grey-brown *fuscus*, umber-brown *umbrinus*.

Veronica Chamædrys; black-blue, *atrocæruleus;* azure, *azureus;* dark-blue, *obscure cyaneus, s. ceruleus;* smoke-blue, *fumatus;* grey-blue, *cæsius.*

20. *Croceus*—Deep yellow.*

21. *Cyaneus*—Deep blue, like Prussian blue, and the flower of the *Gentiana acaulis.*

22. *Flavovireus*—Yellowish-green.

23. *Flavus*—Yellow, as in the early daffodil.

24. *Flavescens*—Yellowish, or pale whitish-yellow.

25. *Ferrugineus*—Yellowish-brown, as the rust of iron.

26. *Fuscus*—Greyish-brown.

27. *Glaucus*—Sea-green, bordering on grey.

28. *Griseus*—Lively grey; and when hoary, white grey, *Canus;* yellow-grey, *lividus;* blue-grey, *cinereus;* red-grey, *murinus;* brown-grey, *luridus;* green-grey, *lucanus.*

29. *Hepaticus*—Liver coloured.

30. *Hyalinus*—Transparent, and like glass.

31. *Lacteus*—Milk-white.

32. *Liliacinus*—Lilac, as in the *Syringa vulgaris.*

33. *Lividus*—Dark greyish-violet.†

34. *Luteus*—A deep yellow; as the outside of the petals of saffron, and the flower of the *Cystus helianthemum.*‡

35. *Miriatus*—Dull red.

36. *Niger*—Black.

37. *Ochraceus*—Yellow, striped with brown; like yellow ochre, or the feathers on the upper parts of the white owl, *Strix flammula.*

38. *Olivaceus*—Olive colour.

39. *Phœniceus*—Crimson, as the flower of the *Pæony.*

40. *Puniceus*—Fine bright red; Carmine, as in *Loberia fulgens.*

41. *Purpureus*—Purple.

42. *Prasinus*—Grass-green, like the colour of the fresh meadows, before there is any mixture of yellow or other colours.

43. *Ruber*—Red.

44. *Rufus*—Carrot colour, or brownish-red orange.

45. *Roseus*—Rose colour, or red-pink; *pallide roseus,* pale pink.

46. *Sanguineus*—Blood colour.

47. *Smaragdus*—Pure green.

48. *Sulphureus*—Bright but pale yellow, without the slightest orange tinge.

49. *Violaceus*—Violet, or deep-bluish purple, as in *viola odorata.*

50. *Vitellinus*—Yellow, verging to orange, as in pale marigold.—*See Symes's Work also.*

* Yellow *luteus,* sulphur-yellow *sulphureus,* whitish-yellow *alboluteus,* straw-yellow *stramineus,* greyish-yellow *flavus,* egg-yellow *vitellinus,* dark-yellow *citrinus,* s. *obscurè luteus,* saffron-yellow *croceus,* ochre-yellow *ochraceus.*

† Violet *violaceus,* dark purple-violet *atropurpureus* s. *obscurè purpureus,* purple-violet *purpureus,* lily-violet *liliacinus.*

‡ Lion-orange *helvolus,* Isabella-orange *Isabellinus,* minium-orange *miniatus,* cinnabar-orange *cinnutarinus.*

In the fabrication, as well as the application of Colours, one false step may completely render useless the labour previously devoted to the subject; and, therefore, in adjusting the proportions of the different components, careful attention is a most desirable accompaniment to skill in the successive peculiar processes. Of the peculiar equilibrium of combinative potency, which produces the great variety of tints in the fine essays of the Art, current knowledge is very defective. "Whatever may be the physical cause of colours, the colouring particles which it is the object of the Art of the [Enameller] to apply to [Porcelain, etc.] are known to possess chemical properties, distinguishing them from other substances, dependent on the *combinative potencies* exercised collectively by their particles, as well as on their reciprocal action, and on their composition, which disposes them, more or less, to assume the solid or the liquid state."—BERTHOLLET.

On the *Incompatibility of Colours* under or upon the same Glaze, as Pink and Mat Blue—Pink, Black, and Brown—Rose Colour, Blue, and Black—Turquoise, Blue, and Black,—Celeste, Pink, and Green, etc., the Manufacturer has been left solely to accident and conjecture—as likewise concerning the proportion of innocuous or indifferent components present in the glaze—probably because of defective comprehension of all the conditions of the subject, and incertitude that they are the general result of the difference, on comparing the quantity of alkali with that of earths, or of oxide of lead, used in the glaze. Another peculiarity also must be mentioned, that the high temperature of

the potter's oven promotes the chemical potency of the lime on the silica present, which thereby is rendered obedient to the solicitings of acids, and of substances prepared by their agency.

Whatever may be the maximum of perfection in each process beyond which it seems impossible to advance, certainly, compared with those prior, the last will usually be the smallest; and as the limit of improvement is rarely approached, except in a few extensive branches of the small number of national Manufactures, the advances will be made, in general, when the former are very numerous, and their utility great and important.

In reviewing the main subjects which form the present volume, I think every person will be convinced that between the Manufacture and the Science of Chemistry there is most important and intimate connection, to which special attention must be paid at every step advanced in the career of improvement. "Science has of necessity, peculiar to itself, a vital energy, a progressive power, superior to the obstacles of time, of things, and of man. Human passions, vulgar ambition, and party interests pass away; but permanent are the labours of science, the sacrifices made for her sake, the victories borne off in her name; and which contribute to enlarge that splendid and profitable heritage, on which, at the present day, is based her real grandeur."—DUPIN.

For any one of our Manufacturers to profitably conduct the smallest establishment of this combination of mechanical and chemical industry, and skill of the manufacturing population, he requires to be

duly supplied with materials, the united product of several of the counties of England. To produce the commonest painted bowl, used by the poorest peasant wife to contain the breakfast of her rustic husband, the clays of Dorset and Devonshires, the flints of Kent, the granite of Cornwall, the lead of Montgomery, the manganese of Warwickshire, and the soda of Cheshire, must be conveyed from those respective districts, and by ingenious processes, the results of unnumbered experiments, be made to combine with other substances apparently as heterogeneous, obtained from other nations.

The accumulation and dissemination of science and knowledge obey laws altogether distinct and different from those obeyed by physical subjects. Unlike the force, by schoolmen named *gravity*, which diminishes rapidly at every successive increment of the distance from the point of contact, its *ideal* origin, or that of combinative potency, which is inert at determined distances, the further the advancement from the origin of our knowledge the greater the ability is, and more adapted to capacitate its possessors to appropriate fresh supplies. Yet this continual and rapid improvement, instead of inciting fears for the exhaustion of the prolific source, at each advance places them in a more elevated position from which they can readily contemplate the several portions they have passed.

Every well-wisher of the Manufacture, who can imagine the vast portion of patient thought, of continued labour, of repeated experiment, of happy efforts of genius, and the great amount of expenses incurred, and which have originated and promoted

its progress to the present state, will feel anxious, as much as possible, to prevent the recurrence of the disappointment, vexation, and loss, consequent on deficient chemical information in the persons who have been entrusted with the execution of important improvements, which, though very considerable within the course of a few years, it is extremely desirable to extend much further, by appropriating all the advantages supplied by various and valuable successive discoveries.

A proud, vain, and heartless sovereign, imagining that his patronage would divert from her general course that important supplier of his exchequer, asked—"What can I do to promote TRADE?" and received for answer the following pertinent remark: "Let Trade take its own course." Deity has kindly enabled man to invent means whereby the productions of Nature can be worked up into articles of comfort and elegance, with the least possible expenditure of manual labour. And when the acquired habits and natural capabilities are carefully regarded in the persons most eminent for practical and theoretical skill, and whose combined efforts are engaged in the general object of improvement, there is presented the greatest probability of success; and that, ultimately, all the talent of each will regard only this sole object—*the art of producing a good article at the lowest possible cost.*

Each of the varied and unnumbered mineral products may become the basis of some future extensive Manufacture, to multitudes of the human family a source of employment and wealth. But the superabundant products of the mine, the crude

treasures exposed constantly to our view, the coal, and iron, and clay—the primary sources of all the wealth and power of Britain—contain within them other and more valuable principles; and their development cannot possibly be too free. Their non-existence in other nations of Europe prevents the rivalry in manufacturing greatness; and ages of research and labour probably will not completely exhaust them and their numerous modifications, perhaps destined to furnish, in perpetual succession, new sources of our wealth and of our happiness.

The idea has prevailed that the processes of Manufacture are too difficult to be comprehended by the person uninitiated; but the general principles and mutual relations of the whole can be by most persons of moderate acquirements, although previous knowledge and some skill are needful for the Manufacturer to direct those whom he employs. The same principle for cultivating one kind of industry applies to all others equally, whether the manual or the fine Arts; the dormant labour, and the inert inventive faculty, need only suitable excitement to produce comfort and wealth. The advancement of a Manufacturer is not always consequent on plans profoundly invested; sparks may kindle the energies of other minds in a suitable condition to pursue the details, and suggestions acquire importance by their objects being thereby presented to the attention of a large manufacturing population.

Bulwer, in his work entitled *England and the English*, says: "Wedgwood was remarkably successful, and yet accomplished his purposes independent of any public School of Design, wherein

could be pursued the requisite studies for high excellence in the Art of inventing patterns for the Manufacture. Necessity excites, or, which is equally proper, admits the exercise of genius. Thomas[Josiah] Wedgwood could apply only a mere few of the most common principles of the Science of Chemistry to improve the proportions of the components of his wares; yet he accomplished his object by obtaining the most beautiful and convenient antique specimens, which by his workmen were imitated with scrupulous exactness; and after having gained celebrity for these copies, he had recourse to Flaxman, *the greatest genius of the day*, for original designs and advice [and Flaxman employed Mr. John Lucock, who on November 5, 1836, showed to myself and a friend his account for work done for Flaxman]. The Manufacturers of 1835 produce a far more excellent and valuable fabric; and yet they are less willing than he was to reward excellence, while they complain of defective talent in persons whom they never excited and solicited, and whose services a moderate remuneration would command."

The *cheapness* of our Manufacturers, the staple of our commerce, involves our national welfare and existence; and the accumulation of skill and talent to promote this, by increasing the facilities for their production, supplies advantages participated by ourselves and our foreign customers. This cheapness involves likewise a suitable course of induction in the people; industry and ability unequalled, expertness and skill in manipulation unrivalled; appropriation of native materials peculiar; the economy of the Manufactory admirably secured and arranged; and

the display of ingenuity in the successive changes of shapes of articles, and of elegance of patterns and decorations, without parallel or limit. This cheapness will command foreign custom, and our markets will have visitors—natives of every clime and country—prompted by self-interest, and the advantages they will derive from supplies of the products of our industry; and also, through the same all-powerful motive, vendors of those commodities for which we proffer a price greater than is obtained in other markets. Such was the real inducement which brought the early dealers in EARTHENWARES to the first marts, Tyre and Sidon, in Phœnicia, and subsequently to Corinth, and to Etruria. And if in the revolutions of time and events a country should be found whose porcelain and earthenware are vended on cheaper terms than those of the potteries of Britain and other nations of Europe then, even were such spot by supposition located in the most remote or obscure nook of our globe, thither will flock all the earthenware dealers; and neither fleets, nor armies, nor any other human power, would prevent the present flourishing borough of Stoke-upon-Trent sharing the fate of its once proud predecessors in Phœnicia, in Greece, and in Italy.

The prevalence of liberal principles in the councils of Britain has tended, remarkably, to excite the talent, genius, enterprise, capital, and industry of the nation; to accelerate the improvement of Manufacturers in comparison with those of rival states; to place them on a vantage ground, only subversive by moral disorders resulting from injudicious in-

structions. In calculating the possible injury this Manufacture may sustain from foreign competition —as items indispensable must be introduced—the facilities of operations, transport, mechanical or automatic aid, etc., must be taken into account. The attempt will doubtless be made by America, whose inhabitants possess equal mechanical genius, plenty of the raw materials, and additional demand, because of the prodigious increase in the amount of population.

Every crate of pottery, every hogshead of porcelain, on quitting the ports of Britain, bears the seeds of intelligence and fruitful thought to the members of some less enlightened community. Every merchant who visits the *locale* of our Manufactures returns home the missionary of freedom, peace and good government. And our steam-engines, which now propel our ships to every port of Europe, and transport our merchandise along our miraculous railroads—the talk of all nations—are advertisements and vouchers for the value of our enlightened institutions.

In conclusion, I beg to express the hope, and to avow the sincere desire, that in a comparative short time this Manufacture will be placed as the *ne plus ultra* among the master-pieces of chemical skill and manual dexterity, creditable alike to our age and country.

THE

CHEMISTRY OF POTTERY.

PART THE THIRD.

TABLES OF THE CHARACTERISTICS OF CHEMICAL SUBSTANCES.

"The striking mixture of simplicity and complexity which here, as in other parts of Nature, offers itself to our notice, depends on the obedience of the primary elements to the numerical laws which govern the composition of derived forms."—WHEWELL.

ACCURATE knowledge of the CHARACTERISTICS of Substances is most advantageous to the votaries of Chemistry. And yet to verify each *seriatim* would require more talent, time, and indefatigable industry in him who might attempt the task, however deservedly eminent, than could be reasonably expected. Those entitled most to general confidence, because results of the researches of different analysts of acknowledged ability, are scattered through many voluminous and expensive works, and reference to them can be made only at a great expense of time and trouble, even where to the works themselves there is facility of access.

Yet to the chemical student such reference is indispensable, until the particulars become familiar by their frequent reiteration; unless they can be presented to him in some arrangement that will supply him readily with the entire amount of current knowledge concerning them. Such an auxiliary for this important purpose is a series of CHEMICAL TABLES, and the only drawback on its utility is the *possible* diminution of the advantage of habitual calculation.

When (in 1831-2) directing the Chemical Class of the Pottery Mechanics' Institution, the desire to present a standard for the researches—of accuracy, when these were imitative, and of comparison when original—could only be gratified by the constant reference to accredited authorities; at a sacrifice I was induced to make, solely in hope thereby to confer an advantage on minds just beginning to expand with fervent attachment to science. But the benefits were so obvious that I became more intent on the design of availing myself of the earliest opportunity to collect and tabulate the observed properties and relations of substances. And without regard to the labour of the task, I have endeavoured to be, in every particular, most attentive to ensure accuracy.

Frequently during these sessions had I been led to notice that certain compounds, whose atomic weights differed, had present the same *relative* yet not the same *absolute* number of atoms of the same elements; that others had precisely the same numbers of the same elements, yet different or opposite properties, or wholly different kinds of substances.

These peculiarities surpassed my ability to refer to an adequate cause ; and I was highly gratified to find from subsequent researches, that the respective combinative potencies which produce such results had engaged the attention of philosophical chemists of the highest celebrity, by them named *Polymerism*, *Isomerism* and *Metamerism ;* and likewise another remarkable peculiarity, noticed especially in natural productions, and named *Isomorphism*—the probable similar form of atoms of certain classes of elements, bases, and acids, whence the *substitution* of an *equivalent* number of atoms of an element or compound (a like-oxidated or electro-positive component) for those of one usually present ; and yet preserving the external characters, and the figure and the angle of the cleavage planes of the crystal. The substituted components being named *vicarious*, and vary, as less of one and more of the other, agreeably to their different combinative potencies.

With regard to natural compounds, although chemists have endeavoured by numerous and most carefully-conducted analyses to discover the nature of the connection between chemical composition and mineral character, yet, as there are not only at present no general and generally-recognised chemical laws, susceptible of application to the various classes of mineral substances, neither many clear determinations of the components of particular species, and so few instances of ability to state the kind of substance, from mentioning very fully the components, that there seemed no likelihood of attaining to accuracy in giving insertion to the published formulæ.

The Series of Tables may not inaptly be compared to a vast granary of a widely-extended domain, containing the different portions of the harvest of Chemical Science already ripe, collected by the perseverance of the laborant and the gleaner, and where to each kind is most carefully assigned its proper situation with regard to all the others, whence it can be either removed or omitted only through inattention or ignorance. The arrangement regards the regular systematic succession from the component *most receptive* to that *most communicative*, and presenting the proper place for any which may hereafter be recognised and determined. It may be stated, that the irregular and outspread surface of the domain itself presents numerous chief divisions, in each of which may be noticed spots, which defy alike the estimate and direction of the surveyor, and the management of the improver; in others are indications of the bassetings of rich ore, which needs to be determined by the observations and experiments of persons who especially cultivate the sciences of calculation; here we find veins scarcely opened, but which will require from those who can devote all their industry and attention, the application of all their ingenuity to determine the precise limits of the veins; their assiduity to avoid whatever obstacles might retard their progress or cause failure in the design; and their most improved methods to pursue those appearances of the lode which promise the supply of the hoped-for object; and there are not wanting others veins where the absence of a common principle in the working, or the indiscriminate choice of means to treat and determine the products, or de-

fective instructions for the acquisition of the object, will be found to have hitherto precluded success.

For the chemical student to economise time, labour, and thought, to indicate the components and quantities of the elements in substances, indispensable are CHEMICAL FORMULÆ, and a clear and brief NOTATION, although to some the requisite numerous symbols may be repulsive. The facility and convenience of a Collection of Symbols representing the known Combinations of Forms, however multifarious, can be duly estimated only by persons familiar therewith. In regard to natural substances, notation is indispensable, because frequently their composition is much too complex to be clearly and distinctly expressed by the resources of the language of Modern Chemistry. In the latest improvements of the science there will be merely needful a change of the *Initial* where a vicarious element is found; and by employing the sign of the element for the *prime* or single atom, and affixing an *exponent* of the multiples, the elements and their ratios in the composition of a substance will be clearly restricted and indicated. This method of employing symbols for the components and equivalents of the elements of a compound, when so frequently employed as to be properly comprehended, will be as useful in the facile indication of chemical combinative potency, as are the Arabic digits in the science of arithmetic.* The

* Dr. Turner states, that, in some instances, the equivalents are so nearly simple multiples of that of hydrogen that they may be taken as such without appreciable error; but in many cases, the numbers given by experiment cannot be reconciled

standard adopted is hydrogen, and its communicative or receptive potency with each other element is indicated by the number affixed to each element in the column next to that wherein is the symbol; thus 4 of oxygen combine with ·25 of hydrogen; therefore hydrogen being ·25, 4 is the combinative potency of oxygen. This latter is also a standard for those substances which do not appropriate hydrogen, their equivalent being determined by the quantity which combines with the equivalent quantity of another substance that does combine with hydrogen; silver, for instance, is indifferent to hydrogen; yet as 27·5 of silver combine with 4 of oxygen, and 4 of this combine with ·25 of hydrogen, then 27·5 is the equivalent number of the combinative potency of silver. And so of all other substances.*

with hypothesis. The following are the numbers which he is disposed to believe very nearly correct: lead 103·6, silver 108, chlorine 35·42, barium 68·7, mercury 202, perhaps slightly higher, but not higher than 2023, nitrogen 14·2, but not lower than 14, and sulphur nearer to 16·1 than 16.—*Third Report of British Association for the Advancement of Science*, p. 399.

* The combining quantities of the elements are determinate weights, and the combining quantities of the gases are determinate measures. Thus a cubic inch of one gas combines with a cubic inch of another gas, and not with a fractional part of a cubic inch. And it is requisite further to state, that that determinate weight of a solid body which combines with a cubic inch of one gas combines also with a cubic inch, or with 2 or 3 or some entire number of cubic inches of another gas, and not with a fractional measure.

There is, consequently, a certain weight of each solid element which is equivalent in combination to a gaseous volume.

If every element could be obtained in the state of gas, the

problem of determining the atomic weights could be at once solved by weighing an equal bulk of each of the gases, since, in reality, the atomic weights would be neither more nor less than the specific gravities of the gases. But unfortunately this method of determining the atomic weights is limited to the few following elements :—

Oxygen	4
Chlorine	9
Hydrogen	0·25
Nitrogen	3·5

to which may possibly be added—

Iodine	32
Mercury	25

Limited, however, as this method of determining the atomic weights is, it is of the greatest importance, being the only direct way of strictly comparing the elementary atoms which has yet been discovered. From the weights of equal volumes of the gaseous elements, we can form a distinct idea of the comparative weights of their atoms ; but every other method of determining atomic weights affords at best what we must denominate PRESUMPTIVE *evidence*, and this, if pretty clear with respect to a number of elements, is often, in regard to others, of the most dubious description. The consequence is, that what are called the atomic weights of a good many elements are merely approximations or guesses.

GENERAL REFERENCES.

FORM: *g*, gas; *ld*, liquid; *pr*, powder; *m*, mass; *cr*. crystal; *ct*, crust; *gr*, grains; *fk*, flakes; *pl*, plates; *nd*, needles; *pm*, prisms; *sc*, scales.

COLOUR: — colourless; *bk*, black; *gy*, grey; *br*, brown; *or*, orange; *r*, red; *v*, violet; *bl*, blue; *y*, yellow; *gr*, green.

THEORETIC COMPOSITION: † Thomson; ‡ Faraday; * Liebig; || Couerbe; § Jules Gay Lussac; ¡ Henry and Plisson; : Pfaff; ¿ Opperman; †† Chevreul; :l: Bussy and Lecanu; ⁂ Boullay; = Brandes; × Guerin; ÷ Grüur; + Pelletier; *U* Ure.

BOILING TEMPERATURE: *v*, volatilises; *s*, sublimes.

SOLUBILITY: *w*, water; *a*, alcohol; *al*, alkali; *ac*, acid.

ATMOSPHERIC ACTION: *d*, deliquescent; *ef*, effervescent.

Name of the Element, and its Combinations.		Form.	Colour.	Symbols of the Components, and their Quantities.	Atom. weight & Equivalent Numbers, Hyd. = 25.	Specific Gravity.		Weight of 100 Cubic Inches, Barom. 30°, Ther. 60°.	Proportional Components.	Components in Volumes.	Resulting Volume.	Fusing Temperature.	Boiling Temperature.	Theoretic Composition.			Trivial Name.
						Water = 1.	Atmospheric Air = 1.							Acid.	Base.	Water.	
OXYGEN.....		*g*	—	O	4		1·1111	34·454									
SULPHUR.....		*g*	*y*	S	4	1·99	1·1111	34·454			sd	216°	550°				
Acid.....	1	*g*	*y*	SO	8		2·2222	69·000									Sulphurous
	2	*g*	*y*	SHO	8·25					S^2O^2							Hypo Ditto
		g	*y*	SHO^2	12·25		1·845		SO	SO^2	l						Oil of Vitriol, Sulph.
	3	*g*	*y*	S^2HO^3	20·25		1·347			S^2O^5							Hypo Ditto
	4	*g*	*y*	SH^2O^3	16·5				S^2O^2	SO^3	sd						Oxygenated Ditto
	5	*ld*	—	$S^5H^3O^4$	32·75						ld						
Chloride.....	1	*ld*	*br*	SCl	13	1·60	3·6111						200°	4·5	4†		
	2	*ld*	*br*	SCl^2	22	1·76	4·7222										
Bromide.....		*ld*	*r*	SB										10	2†		
Iodide.....	1	*pr*	*v*	S^2I	40									15·75	2†		
	2	*pr*	*gy*	SI	36												
Phosphoret.....		*sd*	*br*	S^2P^3	20									3	1†		
Hydro Ditto.....		*ld*	*y*	SHP	8·25												
Chloro Ditto.....		*pr*	*y*	$S^2P^2Cl^3$	43									6·75	2	2†	

NITROGEN.....		*g*	—	Z	3·5		·9722	30·15								
Oxide.....	1	*g*	—	Z^2O	11		1·527	47·377	Z^2O	ZO	2					
	2	*g*	—	ZO	7·5		1·0416	32·302	Z^2O^2	ZO^2	4					
Acid.....	1	*ld*	*y*	ZO^2	11·5				Z^2O^3	ZO^3			82°			
	2	*ld*	*y*	ZHO^3	15·75	1·451			Z^2O^4	ZO^4	ld					Aqua fortis
	3	*g*	*or*	ZO^5	23·5				Z^2O^5	ZO^5			248°			Nitric Acid
	4	*ld*	—	ZH^3O	8·25											
Chloride.....		*ld*	*y*	ZCl^3	30·5	1·653				ZCl^4						
Iodide.....		*ld*	*v*	ZI^3	99·5						sd					
Carburet.....	1	*pr*	*w*	ZC^2	9·5											
	2	*pr*	*w*	ZC	6·5											
Atmospheric Air		—	—	Z^4O	18	1·000		31·0117								
CHLORINE.....		*g*	*gn*	Cl	9	2·5		76·599								
Oxide.....	1	*g*	*y*	Cl^2O	22	2·444					2·5					
	2	*g*	*gn*	ClO^2	17	2·361					4					
Acid.....	1	*g*	*y*	ClO^3	21											
	2	*g*	*y*	ClO^4	25											
	3	*ld*	*y*	ClH	9·25	1·267		39·376	ClH	ClH	2		110°			Muriatic
Iodide.....	1	*g*	*v*	Cl^2I	50											
Hydro carburet...		*sd*	*w*	ClH^2C^2	15·5	1·247	3·4434						148°			
Chloral.....		*ld*	—	$Cl^6C^2O^4$	106	1·502							202°	18·09	70·24	11·659*
BROMINE.....		*g*	*or*	BM	20	3·0	5·3933				ld	116·5°	160°			
Acid.....	1	*ld*	*w*	BMO^3	32					BO^5						
	2	*ld*	*w*	BMH	20·25				BH	BH	l					
Chloride.....		*ld*	*y*	BMCl	29											
Iodide.....		*ld*	*v*	BMI	52											
Carburet.....		*ld*	—	BMC	23											
IODINE.....		*g*	*v*	I	32	4·948	8·678	271·32			sd	225°	220°			
Acid.....	1	*sd*	*w*	IO^3	44											
	2	*sd*		IHO^3	44·25	1·7	4·4090	136·737	HI	HI	l					
	3	*sd*	*or*	IHO	36·25						sd					

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						Water = 1.	Atmospheric Air = 1.							Acid.	Base.	Water.	
Chloride	1			I^2Cl	73												
	2			ICl	41												
Bromide	1			I^2BM	84												
	2			IBM	36												
Carburet		*cr*	*w*	IHC	35·25												
ELUORINE		*g*	*w*	F	4·5	1·0609					sd						
Acid		*g*	—	FH	4·75	1·25					ld						
PHOSPHORUS.		*g*	*y*	P	4	1·778					sd	108°	550°				
Hydrate		*ld*	*w*	P^2H^3	8·75												
Oxide	1	*fk*	*w*	PO	8												
	2			PO^3	12												
	3			PO^5	24												
Acid	1	*sd*	*br*	P^2O^3	20												
	2	*pr*	*y*	P^4O^3	28												
	3	*sd*	*br*	P^2O^5	28												
	4	*ld*	*w*	PH	4·25												
	5	*sd*		PH^3	4·75												
	6			P^5HO^2	28·25												
Sulphuret	1	*sd*	*br*	PS	8												
	2	*sd*	*y*	PS^2	12												
Chloride	1			PCl	13												
	2	*ld*		P^2Cl^3	35	1·45							200°				
	3	*sd*		P^2Cl^5	53												
Bromide	1			PBM^3	64												
	2		—	PBM^5	104												
Iodide	1	*sd*		P^2I	40												
	2			PI	36												
	3			PI^2	68												
	4			P^2I^5	168												

Fluoride				P^2F^3	21·5										
Seleniuret	1			PSE	14										
	2			PSE^3	34										
	3			PSE^5	54										
BORON		*pr*	*bn*	B	1	1·183					sd	600°			
Acid	1	*pl*	*bn*	B^2O	6	1·479									
	2	*ld*	*br*	BH^2F	6		2·3622		BF^3						
	3	*ld*	*y*	BO^2	9										
Sulphite	1	*m*	*w*	BS	5									2	1†
	2			BS^2	9										
Chloride		*g*	*w*	BCl^2	19	3·9420									
Fluoride		*g*	—	BF^3	14·5	2·3124									
Boride		*g*	—	B^2BO^2	11										
CARBON		*g*	—	C	3		·4166	12·923							
Diamond		*sd*	*v*	C	—	3·52									
Oxide		*g*	—	CO	7		·9722	30·150	CO	C^2O	2				
Hydruret		*ld*	—	CH^2	3·5		·5554	17·23	CH		1				
Acid		*g*	—	CO^2	11				CO^2	C^2O^2	2				
Chloro Ditto		*g*	*gn*	CClO	16		3·4421	106·749			1				
Sulphite	1	*ld*	—	CS^2	11	1·272							110°	4	0·75†
	2	*pr*	*bk*	CS^4	19										
	3	*sd*	*bn*	$CSCl^2O^2$	33									9+1+	2+1+
Chloride	1	*g*	—	C^2Cl	15		3·4722								
	2	*ld*	—	CCl	12	1·5526							170°		
	3	*sd*	*w*	C^2Cl^3	33	2·00						250°	450°		
	4	*ld*	*w*	C^4Cl^5	57							320°	360°		
Bromide		*ld*	—	CBM	23										
Iodide	1	*sd*	*y*	CI	35	2·00									
	2	*sl*	*y*	C^2I^3	102										
Phosphoret		*sd*	*bn*	CP^2	11										
Naphtha		*ld*	*y*	C^6H^6	19·5	·758							186°		
Naphthaline		*sd*	*bn*	C^3H^2	9·5	1·23						180°			
Sulpho Do. Acid		*sd*	*w*	$CS^2H^3O^5$	33							212°	410°	93·75	6·25‡
Cyanogen		*g*	—	C^2Z	9·5	1·8055	5·5996								

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					Water = 1.	Atmospheric Air = 1.							Acid.	Base.	Water.	
Sulphuret	*sd*	*y*	CZS^2	14·5												
Chloride	*sd*	*y*	$CZCl^2$	24·5							248°	374°				
Bromide	*cr*	—	CZBM	26·5								59°				
Iodide	*cr*	*w*	CZI	38·5												
Phosphite.....	*pr*	*y*	CZP	10·5												
Cyanous Acid	*g*		CZHO	10·75												
Cyanic Acid	*ld*	—	CZO	10·5												
Hydro Ditto A. ...	*ld*	—	CZH	6·75	·7058	·9374						79°				
Sulpho Ditto A....	*ld*	—	$CZHS^2$	14·75	1·022							216·5°				
Chloro Ditto A. ...	*ld*		CZCl	15·5		2·1527										
Ferro Ditto A....	*sd*		CZHFE	13·75												
Cyanuric A.	*sd*	—	CZO^2	14·5								680°				
Carbazotic A.			$C^{10}Z^4O^{10}$	83·5												
Chloro Do. A.			CZClO	19·5		3·4421	106·749			1						
Oxalic A.	*cr*	*w*	C^2O^3	18							209°	330°				
Chloro Do. A.	*lb*	*w*	$C^2Cl^2H^2O^3$	36·5							112°	390°				
Oxamid	*pr*	*w*	$C^2ZH^2O^2$	19												
Croconic A.			C^5O^4	31												
Mellitic A.			C^4O^3	24												
Formic A.	*fd*	—	C^2HO^3	18·25	1·1168											
Acetic A.	*ld*	—	$C^4H^3O^3$	24·75												
Pyro Do. A.	*ld*	—	C^3H^3O	13·75	·7921							132°				
Tartaric A.	*cr*	*w*	$C^4H^2O^5$	32·5												
Pyro Do. A.	*cr*	*w*	$C^4H^3O^4$	28·75							212°	221°	24·244	3·030	32·326 ÷	
Lactic? A.	*cr*	*y*	CHO													
Vinic A.			CHO													
Sulpho Do. A.			CHSO													
Chloro Do. A.			CHClO													
Do. Vinous A.			CHClO													
Citric A.			$C^4H^2O^4$	28·5												
Pyro Ditto A.			C^4HO^3	24·25												
Malic A.			C^4HO^4	28 25												
Pyro Ditto A.			CHO													
Racemic A.			$C^4H^2O^5$	32·5							100°	200°				

Pyro Ditto A.	*ld*	*w*	CHO										
Fungin			CHO										
Fungic A.			CHO										
Mucic A.			$C^6H^5O^8$	51·25									
Pyro Ditto A.			$C^9H^2O^6$	51·5									
Succinic A.			$C^4H^2O^3$	24·5									
Benzule	*cr*	*w*	$C^{14}H^6O^2$	51·5									
Benzoic A.	*ld*	*w*	$C^{14}H^5O^3$	55·55									
Meconine			$C^9H^9O^4$	45·25						60·247	4·756	34·997‖	
Meconic A.			CHO										
(Pelletier's New) A	*cr*	—	$C^{18}Z^3H^{21}O^{10}$	112·75						49·76	9·50	4·78	35·96 ×
Paraffin	*sd*	*w*	CH	3·25	0·87		78°			85·22	14·98§		
Eupion	*sd*	*bn*	CH^2	3·5	0·74			336°					
Gallic A.			CHO										
Pyro Ditto A.			$C^6H^3O^3$	30·75									
Ellagic A.			CHO										
Corticin			CHO										
Elaine			CHO										
Elaïdic A.			CHO										
Elaidine			CHO										
Elai-iodic A.			CHIO										
Camphor	*sd*	*w*	$C^{12}H^9O$	42·25	·988		288°	400°					
Camphoric A.			$C^{10}H^{15}O^5$	53·75									
Erythrin			CHO										
Pseudo Ditto			CHO										
Erythric A.			$C^{16}H^{16}O^4$	68									Rocellic of Huren.
Erythrogen			CHO										
Pectin			CHO										
Pectic A.			CHO										
Caffein			CZHO							39·8	20·8	6·6	32·8 :
Caffeic A.			CHO							29·1	6·9	6·4 :	
Cinchonin			$C^{20}Z^2H^{22}O$	76·5			329°			77·81	8·87	7·37	5·93*
Quinine			$C^{20}Z^2H^{24}O^2$	81			248°			75·76	8·11	7·52	8·61*
Kinic A.			$C^{15}H^{12}O^{12}$	96									
Pryo Ditto A.			CHO										
Caincic A.			$C^8H^7O^4$	41·75									
Asparagin			$C^6Z^3H^{12}O^4$	50·5						38·38	22·46	6·24	34·41 ¡
Aspartic A.			CHO							73·56	9·86	16·58 ¡	
Arabine	*sd*		$C^6H^5O^5$	39·25						48·81	0·14	6·2	49·85 ×
Bassorine	*sd*		$C^{10}H^{11}O^{11}$	76·75						37·28	6·85	55·87 ×	

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					Water = 1.	Atmospheric Air = 1.							Acid.	Base.	Water.	
Cerasine			$C^6H^5O^5$	39·25									48·81	0·14	6·2	49·85 ×
Amyrine			CHO										81·04	10·474	8·486 ¡	
Caryophillin			CHO										81·92	12·25	5·73 ¡	
Styracin			CHO										76·273	5·563	18·22 ¡	
Auradin			CHO										83·76	15·09	1·15 ¡	
Piperin			CHO										76·10	10·27	13·63 ¡	
Picrotoxin			$C^5H^6O^2$	24·5									61·153	6·22	32·24 ¿	
Berberin			CZHO										60·3	13·2	4·4	22·1 +
Narcine			$C^{16}ZH^{84}O^8$	89·5									54·73	4·33	6·52	34·42 +
Emetine			$C^{37}Z^2H^{54}O^{10}$	171·5									64·57	4·3	7·77	22·95 +
Narcotine		—	$C^{17}ZH^{17}O^5$	78·75									65·16	4·31	5·45	25·08 +
Conüm	*ld*		$C^{12}Z^2H^{28}O$	54	0·89							308°	66·913	12·805	12·	8·282*
Morphine			$C^{34}Z^2H^{36}O^6$	142									72·34	4·995	6·366	16·299*
Strychnine			$C^{30}Z^2H^{35}O^3$	117									76·43	5·81	6·7	11·06*
Brucin			$C^{32}Z^2H^{36}O^6$	136									70·88	5·07	6·66	17·39*
Suberic A			CHO										37·25	15·98	46·76 =	
Ulmic A			CHO										56·7	4·8	38·5 ⁝⁝	
Azulmic A			CZHO													
Stearine			CHO													
Stearic A			CHO										70	75	5 ††	
Ricinic A			CHO										73·56	16·58	9·86 ⁝:	
Margaritic A		*w*	CHO										79·5	18·6	10·0 ⁝:	
Margaric A	*cr*	—	CHO								140°		34	65	5 ††	
Oleic A	*ld*		CHO		·898								70	17	5 ††	
Phocenine			CHO													
Phocenic A			CHO										80·5	11·5	7·5	
Bytyrine			CHO													
Butyric A			$C^8H^{11}O^3$	38·75												
Hircine			CHO													
Hircic A			CHO													
Delphine			CHO													
Delphinic A		*y*	$C^{10}H^{14}O^3$	45·5												
Glycerine	*ld*		$C^3H^3O^2$	17·25	1·27								40·1	8·9	51	
Cetine			CHO													

Cetic A.			CHO															
Ambreine			CHO															
Ambreic A.			CHO															
Castorine			CHO															
Castoric A.			CHO															
Ethal			CHO															
Capric A.			$C^{18}H^{20}O^{3}$	73·25														
Caproic A.			$C^{12}H^{19}O^{3}$	52·75														
Gliadine			CHO															
Cholic A.			CHO															
Cholesterine	*cr*	*w*	CHO								278°		85·1	11·9	3			
Cholesteric A.			CHO															
Salacin			$C^{4}H^{5}O^{2}$	21·25									54·49	6·38	38·13§			
Santonin			CHO										51·34	9·76	38·9			
Columbin			$C^{7}H^{7}O$	26·75									66·36	6·17	27·47*			
Sinapisin			CZHSO										57·92	4·94	7·795	9·657	19·688	
Sinapic A.			CZHSO															
Pollenin			CHO															
Taurin			CHO										40·0	11·7	48·3			
Palmine			CHO															
Palmic A.			CHO															
Cerain			CHO															
Cerin			CHO															
Ceric A.			CHO															
Pinic A.			CHO															
Silvic A.			CHO															
Crystallin			CHO															
Indigotic A.			$C^{15}Z^{2}O^{10}$	92														
Nitrohemic A.			CZO															
Allentoic A.			$C^{5}Z^{4}H^{8}O^{4}$	51														
Mannite	*cr*	*bn*	$C^{4}H^{9}O^{4}$	30·25														
Urea	*cr*	—	$C^{2}Z^{2}H^{4}O^{2}$	24	1·35						248°							
Uric A.	*ld*	*w*	$C^{10}Z^{4}H^{3}O^{4}$	64·75														
Purpuric A.	*pr*	*r*	CZHO															
Erythric A.	*cr*	—	CZHO															
Atropin			CZHO															
Atropic A.			CZHO															
Solanin			CZHO															
Solanic A.			CZHO															
Daphnin			CZHO															

Name of the Element, and its Combinations.	Form.	Colour.	Symbols of the Components, and their Quantities.	Atom. weight & Equivalent Numbers, Hyd. = 25.	Specific Gravity.		Weight of 100 Cubic Inches, Barom. 30°, Ther. 60°.	Proportional Components.	Components in volumes.	Resulting Volume.	Fusing Temperature.	Boiling Temperature.	Theoretic Composition.			Trivial Name.
					Water =1.	Atmospheric Air=1.							Acid.	Base.	Water.	
Cocco Guidic A.			CHO													
Hyoscyamin			CZHO													
Veratrin			CZHO													
Cevadic A			CZO													
Nicotin			CZHO													
Nicotianin			CZHO													
Xanthine			CZHO													
Alizaric A			CZO													
Violin			CZHO													
Violic A			CZO													
Viridous A			CZO													
Viridic A			CZO													
Morin			CZHO													
Moroxylic A			CZHO													
Lactusic A			CHO													
Valerianic A			CHO													
Igasuric A			CHO													
Equisetic A			CHO													
Lichenic A			CHO													
Laccic A			CHO													
Crameric A			CHO													
Fumarin			CZHO													
Fumaric A			CHO													
Cinin			CZHO													
Cinic A			CHO													
Amylic A			CHO													
Aconitic A			CHO													
Conic A			CHO													
Daturic A			CHO													
Ginkaric A			CHO													
Polygalic A			CHO													
Tanacetic A			CHO													
Absinthic A			CHO													
Phytolaccic A			CHO													

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Name of the Element, and its Combinations.	Form.	Colour.	Symbols of the Components, and their Quantities.	Atom. weight & Equivalent Numbers, Hyd. = 25.	Specific Gravity.		Weight of 100 Cubic inches, Barom. 30°, Ther. 60°.	Proportional Components.	Components in Volumes.	Resulting Volume.	Fusing Temperature.	Boiling Temperature.	Theoretic Components.			Trivial Name.
					Water = 1.	Atmospheric Air = 1.							Acid.	Base.	Water.	
Amygdalin			C H O													
Laurine			C H O													
Variolarin			C H O													
Lignin	*m*	*w*	C H O										51·43	5·82	42·73	
Hordein			C H O													
Tremellin			C H O													
Digitalin			C Z H O													
Smilacin			C Z H													
Guaranin			C Z H O													
Corydalin			C Z H O													
Cynapin			C Z H O													
Sanguinarin			C Z H O													
Curarin			C Z H O													
Esembeckin			C Z H O													
Hyssopin			C Z H O													
Eupatorin			C Z H O													
Quercin			C Z H O													
Buxin			C Z H O													
Alcohol	*ld*	—	C^2H^3O	10·75	·769	1·5972						176°				
Ether	*ld*	—	C^4H^5O	17·25	·700	2·569						98°				
Wax	*m*	*w*	$C^{13}H^{11}O$	45·75							150°					
Fibrin	*m*	*w*	$C^{18}Z^3H^{14}O^5$	91												
Albumen	*ld*	*y*	$C^{15}Z^2H^{14}O^6$	79·5												
Gelatine	*sd*	*w*	$C^{15}Z^2H^{14}O^6$	79·5												
Tannin			C H O													
Spermaceti											212°		52·69	38·6	43·45	
Turpentine			C H O		4·765							312°				
HYDROGEN	*g*	—	H	·25		·0694	2·153									
Water Vapour		*w*	H^2O	4·5	1·	·6230	19·32									

Oxide.....	1	*g*	—	H O	4·25												
	2	*ld*	—	H O^2	8·25	1·452											
Sulphuret.....	1	*g*	—	H S	4·25		1·1805										
	2	*g*	—	H S^2	8·25	1·1788											
Phosphoret.....	1	*g*	—	H P	4·25		1·214	37·649						4	·125†		
	2		—	H P^2	8·25		1·761							3	·375†		
Seleniuret.....		*g*	—	H Se	10·25												
Arseniuret		*g*	—	H^2As^2	19·75	2·695											
Telluret.....		*g*	—	H Te	8·25												
Silicet.....		*g*	—	H Si	2·25												
Carburet..... ..	1	*g*	—	H^2C	3·5	·5555	·4861										
	2	*g*	—	H^2C^2	6·5	·9722	2·7083										
	3	*g*	—	H C^2	6·25	2·70											
Chloro Ditto.....		*g*	*y*	$H^2C^2Cl^3$	33·5	·4861											
Olefiant Gas.....		*g*	—	H^2C	3·5		·9722	30·153									
Gas of Marshes...		*g*	—	H^4C	3		1·9444										
		g	—	H^3C	3·75		1·4583										

OBSERVATIONS.

Oxygen is without colour, or odour, or action on tincture of litmus, or on lime-water; it is partially soluble in water, and increases the energies of animals, and the force of combustion. It is present with most substances, but its aciduline potency involves the presence also of hydrogen.

Sulphur. *Sulphurous Acid* has a remarkable pungent odour, destroys fermentation and vegetable tints, liquefies under the pressure of two atmospheres at 45° F., and in 33 volumes combines with water. Its presence with bases is indicated by a *white* precipitate of tests 20, 30, 35, not soluble in water, but in acids. With the alkalies and earths it forms salts named *Sulphites*, those of the former being soluble, of the latter insoluble in water; these salts appropriate oxygen from nitric and nitrous acids, also sluggishly from the air, forming *sulphates* by their decomposition, but the sulphurous acid evolves in effervescence, when is present either sulphuric, muriatic, phosphoric, or arsenic acid. Ignition with charcoal forms the greater number into sulphurets, and the action of heat alters them into a sulphate, or an oxide, or a metal. When perfectly dry they resist the action of chlorine; but when moisture is present, the gas of the acid evolves, and leaves a sulphate and a muriate. *Hyposulphurous Acids* forms the salts named *Hyposulphites*, all of which are decomposed by either sulphuric, muriatic, fluoric, phosphoric, or arsenic acid, the sulphurous acid gas evolves, the sulphur precipitates, and a fresh salt results. Its presence is indicated by a *white* precipitate when test 30, 32, or 35 is exhibited. The hyposulphates of the alkalies are very soluble, others less so, in water; the solution dissolves recently-prepared chloride of silver, and acquires intense sweetness, without metallic savour. *Oil of Vitriol* of the strongest kind freezes at 15° F., and of 1·78 at 32°, and solidifies at 45°. The fuming acid of Nordausen is 1·9. On exhibiting test 20, 30, 35, a white insoluble precipitate results, also from nitrate of barytes and nitrate of lead (extremely

corrosive). The salts formed are named *Sulphates*, which decompose at a high temperature with boracic or phosphoric acid present; those of the alkalies and alkaline earths are indifferent to heat, unless mixed with charcoal, when they change into sulphurets; the others are by heat decomposed (except that of lead, which also is soluble in plus of nitric acid, muriatic acid, and caustic potash); those of barytes, lead, tin, bismuth, mercury, and antimony, are wholly, and those of strontian, lime, yttria, cerium, and silver, are partially indifferent to the action of water, which efficiently solicits the others to combination. *Hyposulphuric Acid* is without odour; and with barytes, strontian, and the oxides of some metals, forms the salts named *Hyposulphates*, soluble in water, but some wholly, others sluggishly, indifferent to the action of the atmosphere, or becoming sulphates; yet boiling changes them into sulphates and sulphites. Ignition causes sulphurous gas to evolve, and transforms them into sulphates. On exhibiting to any of these salts concentrated sulphuric acid, or hot diluted, much sulphurous gas evolves, decomposing the hyposulphuric acid, which latter evolves unaltered when the diluted acid is cold. *Hydrosulphuric Acid.*—The sulphurets of the alkalies and alkaline earths dissolve in water, and in air the *hydrosulphurets* decompose; and of these the solutions are decomposed by the acids appropriating the base, while sulphuretted hydrogen evolves, yet the sulphur remains present, only precipitating when plus of nitric or nitrous acid is exhibited. The readiest solvent of sulphurets is dilute muriatic acid. The salts of the alkalies and alkaline earths are indifferent to the soluble hydrosulphurets, which behave to the others in exhibiting white or coloured precipitates. The *Chlorides* are red by reflected light, but by transmitted yellowish-green.

Nitrogen is without colour or savour, and is not easily discriminated; it destroys combustion and vitality, and does not precipitate the lime present in lime-water. The *Protoxide* has a weak pleasant odour and sweet savour; it greatly excites vitality and combustion; is appropriated by equal volume of water, and is liquid under pressure of 50 atmospheres at 45° F. The *Deutoxide*, or nitrous gas, is without colour until atmospheric air or oxygen is present, when brilliant red acid vapour (or nitrous acid gas) appears; it destroys vitality and combustion, does not alter litmus tincture, and about 6 or 8 per cent. is appropriated

by water. *Nitrous acid gas* is red, and forms the salts named *Nitrites*, having one dose (a third) of oxygen less than *Nitrates*. It is very volatile, extremely corrosive, and when in small quantities added to water, there result deutoxide and nitric acid. All the *Hyponitrites* already formed are soluble in water, detonate when mixed with charcoal and ignited, by heat decompose, and the acid evolves into oxygen and nitrous acid or nitrogen; and some of them when slightly heated in air appropriate its oxygen and become nitrates. When sulphuric, nitric, muriatic, phosphoric, fluoric, arsenic, or some other strong acid is exhibited, red vapour evolves, and their acid is converted into nitric acid and nitric oxide. Theory now proves that *Aquafortis* is a true nitrate, having a dose of hydrogen in place of one of a metal. *Nitric Acid* is very corrosive, and, like nitrous acid, powerfully oxidates substances; boiling will increase this potency till the specific gravity of the acid is 1·42, when continued boiling diminishes it; it freezes at 50° F. The salts named *Nitrates*, when mixed with combustibles, charcoal, sulphur, phosphorus, etc., detonate on being ignited; they are soluble in water readily or partially as there is plus or minus of acid present; they all decompose by high temperature, and by interchange of acid, when there is exhibited sulphuric, phosphoric, fluoric, or arsenic acid; and muriatic acid resolves with it into chlorine and nitrous acid, forming the *Aqua Regia* employed to dissolve gold and certain other metals. The *Chloride* is like oil; it distils at 160°, explodes at – 212°, and with combustibles is very explosive. The *Iodide* must be carefully treated, for slight pressure will cause the moist, as drying will the loose, mass to violently detonate.

Chlorine is a yellowish-green gas, which under pressure of more than 4 atmospheres, at 60° F., liquefies into a dark yellow oily substance; its odour is suffocating, yet the gas supports combustion; with little water present fine yellow crystals form, but with much the *liquid* is permanent; it bleaches all vegetable fabrics readily, but sluggishly affects animal productions in cloth. The *Protoxide* and *Peroxide* are deep green in colour, and explode violently, the former with the warmth of the hand, the latter at 212° F.; the former rapidly, the other about 8 volumes, mixes with water; and both powerfully bleach vegetable fabrics. *Chloric Acid* is decomposed, and its oxygen appropriated, by several strong acids, muriatic, sulphurous, phosphorous, etc. The

salts named *Chlorates* are all (except that of mercury) soluble in water, and many of them likewise in alcohol; yet no base will form a precipitate in these solutions. On being ignited, dry chlorates by their oxygen evolving are converted into chlorides, which dissolve in water, and copiously precipitate when test 32 is exhibited. On being carefully warmed with a little dilute muriatic acid, the *greenish-yellow* protoxide of chlorine evolves; when a very minute portion of a chlorate is treated with concentrated sulphuric acid, the peroxide of chlorine evolves; but plus of the salt involves liability to explosion; and flame will evolve when 5 parts of a chlorate are treated with 1 of the fuming sulphuric acid. The chlorate of potash, mixed with any combustible, is extremely explosive, by heat resolving into oxygen and chloride of potassium, and decomposable by sulphurous, sulphuric, or muriatic acid. *Perchloric Acid* readily detects the presence of potash, because the compound requires 65 parts of water, and is insoluble in alcohol. *Muriatic Acid* is a real chloride, having a dose of hydrogen instead of one of a metal. Under the pressure of four atmospheres, at the temperature of 50° F., it is liquid; freezes at 60°; test 32 precipitates white, curd, soluble in ammonia but not in nitric acid. Except the chloride of silver, all chlorides are soluble in water, forming the compounds named *Muriates;* most of these with plus of base are insoluble in water, those of the earths and alkalies are indifferent to the action of hydrogen, which efficiently solicits the others; potash, also soda, decomposes all muriates of other bases; and the water present in the pores of charcoal aids its potency over them. Many of the chlorides are by heat volatilised; but only those of some of the noble metals (gold, platinum, etc.) are decomposed; this results also when to many of them sulphuric acid is exhibited, as chlorine evolves when they are treated with nitric acid. The *Carburet* is volatile, and is called *Chloric Ether*. *Chloral* is oily and transparent, but with water, agitation forms a white solid hydrate.

Bromine is a very volatile orange-red vapour, which peculiarly affects the temples and eyes (as chlorine does the throat, and iodine the nose); but the chloric, bromic, or iodic acid is not supplied by Nature; with little water it crystallises of a beautiful hyacinth red, but with much water the liquid is permanent. It bleaches vegetable tints, displaces iodine, is displaced by chlorine, appropriated by water, alcohol and ether, and forms the salts

named *Bromides*, many of which, in nitric acid, lose a portion of their element, and a solvent of gold is formed. *Bromic Acid*, with characters much like chloric acid, is decomposed by sulphurous acid; as its salts, named *Bromates*, are by concentrated sulphuric acid, while bromine gas and oxygen evolve. This latter effect also ensues on ignition, when *Bromides* result. The bromates are all sluggish or indifferent to the action of water; and, like chlorates, the mixture with a combustible is explosive. *Hydrobromic Acid* is colourless, but has a pungent odour, and is quickly appropriated by water. When the bromides, soluble in water, have their resulting hydrobromates treated with sulphuric acid, the exhibition of chlorine causes to evolve the bromine, which renders sulphuric ether *golden yellow*, in which starch causes an *orange* precipitate. The *Carburet* is volatile, has an aromatic odour, sweet savour, sinks in water, and solidifies at 21° to 23° F.

Iodine is black, crystalline, with a weak odour (already noticed), sharp acrid savour, slight bleaching power on vegetables, volatilises in a beautiful violet vapour, discolours the skin; soluble in alcohol, indifferent to the action of water (except 1-7000 part), with a cold solution of starch an intense *blue* tint ensues, which hot water destroys; chlorine and bromine separate it from its compounds. *Iodic Acid* by fusion is decomposed, also by sulphuric acid; it is indifferent to alcohol, but soluble in water, and with many of the vegetable alkalies forms compounds indifferent to water. Some of the *Iodides*, and most of the *Iodates*, are sluggish, others indifferent to water, even those of metals which decompose it. Hot muriatic acid and sulphurous acid, very readily, but sulphuric acid sluggishly, decomposes the iodates; as does a dull red heat, when oxygen only, or this with iodine, evolving, an iodide results. Like chlorates and bromates, when mixed with combustibles, iodates detonate, but less violently, on being heated. *Hydriodic Acid* has a pungent odour, and is appropriated by water, and the *Chloriodic Acid*, with orange tint, forming two compounds, a chloride soluble in ether, alcohol and water; and perchloride resolvable into muriatic and iodic acids. The *Carburet* sinks in sulphuric acid, and has an aromatic odour and sweet savour. The *Hydriodates* acquire an *orange* tint by appropriating iodine. Chlorine appropriates the hydrogen of these, which are decomposed also by sulphuric or nitric acid, and

the liberated iodine is detected by the blue tinge given to a solution of starch. Hydriodates, in solution, supply to test 20 a precipitate, *russet* coloured, concentrated, *primrose*, when diluted; and *scarlet* to chloride of mercury.

Fluorine is not isolated, but when liberated from one element combines with another. The *Hydrofluoric Acid* is a real fluoride having a dose of hydrogen instead of one of a metal. At 32° it is fluid, yet extremely volatile, rapidly appropriated by water, powerfully acts on silicates and animal fibre. The *Fluorides* of potash, soda, ammonia, and silver are soluble in water, the other in plus of acid. Those of the alkalies with excess of acid form, with some metallic oxides, salts sluggishly soluble. Dry fluorides are indifferent to the action of heat; but moistened, some of them are decomposed, because from the water the hydrogen evolves, changing the fluorine into hydrofluoric acid, which evolves as white acrid vapour that corrodes glass. Hydrated sulphuric, phosphoric, and arsenic acid, will decompose the fluorides, the water also decomposing, and its hydrogen acting as just stated, while the resulting hydrofluoric acid evolves as already mentioned. *Fluosilicic Acid* most potently solicits water to 3·65 its volume, and much silica is deposited.

Phosphorus is extremely inflammable, and so rapidly appropriates the oxygen of the atmosphere, as to enter into combustion on a slight rise of temperature; the ordinary rise of this, on a summer's day, has been known to cause this with phosphorus laid on coarse blotting-paper. *Hypophosphorus* and *Phosphorus Acids* have intense deoxidating potency, and the latter appropriates the oxygen of the atmosphere. The *Phosphites* are, many wholly, others partially, indifferent to water; but by the presence of chlorine, concentrated nitric acid, the peroxide of mercury, and the oxides of several other metals, become phosphates. At the temperature 60° F. they are indifferent to oxygen; but when excluded from the air, and the temperature is raised, phosphoretted hydrogen evolves, a little phosphorus is eliminated, and a subphosphate remains. *Phosphoric Acid* is very deliquescent; the *Protochloride*, as also the *Perchloride*, is separated into muriatic and phosphoric acids when water is present; at a low temperature the *Iodide* is formed, which, when water is present, resolves into hydriodic and phosphoric acids. The *Phosphates* of the alkalies and acids are soluble in water, and those of the

earths, etc., are so in nitric acid; they are sluggish towards sulphuric acid, but caustic and carbonated alkalies precipitate them slightly altered in aciduline solutions, and a *yellow* precipitate obeys the cautious exhibition of test 32; they are, alone, indifferent to the action of heat; but mixed with charcoal, either phosphorus evolves, or they become phosphorets.

Boron is a dark-olive powder, without odour or savour which, when heated in a close vessel, shrivels without volatilising; but in air, inflames and forms dry *Boracic Acid*, soluble in alcohol, and tinging flame green. The salts are named *Borates*, and all are almost indifferent to water, those of the alkalies being least so; at a high temperature most of them melt, and then solicit and become tinged by most metallic oxides; those of the alkalies and earths, never, but those of the other bases partially, are decomposed when ignited with charcoal, sulphur, etc.; also by sulphuric acid, etc. The *Chloride*, when water is present, which it powerfully solicits, resolves into muriatic and oracic acids. *Fluoboric Acid* solicits water to ·700 times its volume, and acts powerfully on animal matter.

Carbon (except as diamond) is dull, black, opaque, and inflammable; it powerfully solicits oxygen in forming *Carbonic Acid*, also hydrogen, forming the gas now used to illuminate our towns; it is insoluble in water, infusible by heat, and incapable of being volatilised; as charcoal, it destroys fetid odours; and also many tints of colour fade when boiled in water with charcoal present, and with many bases it forms *Carburets*. *Carbonic Oxide* burns with a blue flame, and when equal volumes of it and protoxide of nitrogen have the electric spark passed through them, the additional oxygen obtained forms equal volumes of *Carbonic Acid* and nitrogen. This acid liquefies under the pressure of two atmospheres at 45° F. evolves during fermentation, and is absorbed by water, which lime renders milky; it destroys vitality and combustion, and with a few bases forms the salts named *Carbonates*, of which only those of the alkalies solicit water to combination, though many by excess of acid become *Bicarbonates*, which excess again evolves during boiling; and when mixed with charcoal, sulphur, silica, etc., they are decomposed by heat, to which latter the carbonates of potash, soda, lithia, and barytes are indifferent; that of ammonia is volatile; the acid evolves during effervescence when acids are present.

The *Hydrite* powerfully solicits water, and when one volume of gas and four volumes of chlorine over water are exposed to light, carbonic and muriatic acids result. The destructive fires of coal-mines originate in the ignition of this gas in the proportion of one or more volumes to fourteen of air. The *Chlorocarbonic Acid*, called also *Phosgene* gas, combines with four volumes of ammoniacal gas; and when water is present, it resolves into carbonic and muriatic acids. The *Sulphite* is colourless, extremely refractive, inflammable, volatile and offensive. The *Bichloride*, soft and fibrous, fuses easily, is soluble in alcohol, and crystallises, and likewise the *Perchloride*, which has an aromatic odour, and may be distilled; and much similar in odour and savour is the *per-iodide*. *Naphthaline* has an aromatic odour, and combines with sulphuric acid; and the *Sulpho-naphthalic acid* is readily dissolved by alcohol and water, and with bases forms salts. *Cyanogen* burns with a crimson flame, liquefies by the pressure of – 4 atmospheres, at 45° F. water appropriates 45, and alcohol 23 volumes. The *Sulphuret* compound (C^2 ZH S^2) 3 and water 1, form red crystals. The *Bromide* is colourless, volatile, and by caustic potash forms hydro-cyanate and hydro-bromate of potash. The *Iodide* is volatile, caustic, sinks in sulphuric acid, and is indifferent to a temperature of 212° F. *Cyanic Acid* with ammonia forms *Urea*, with water present resolves into ammonia and carbonic acid; and with a solution, oxide of lead, or of silver, forms an insoluble precipitate. *Hydrocyanic Acid* is a very powerful poison, and at 0·999 spec. grav. is employed for medical purposes, which chlorine decomposes; the acid is volatile, and the odour is rather fragrant like peach blossoms; at zero it freezes. The *Sulphocyanic Acid* with protoxide of copper forms a white salt, but a blood-red one with peroxide of iron. The *Chlorocyanic Acid* is a gas at 60° F., fluid between 5° and 10·5°, and solid at zero. The *Ferrocyanic Acid* with potash and iron forms the valuable compounds Prussian blue and prussiate of potash. *Cyanuric Acid*, in transparent crystals, remains indifferent to boiling sulphuric or nitric acid. *Oxalic Acid* crystallises with three proportions of water, two of which escape as steam by boiling; boiling-water appropriates a quantity at present (1836) not determined, it appropriates the most minute portions of lime present in a neutral solution; by heat the *Oxalates* decompose into a metal, oxide, or carbonate; and pouring sulphuric acid on

binoxalate of potash causes carbonic acid gas and carbonic oxide to evolve, and when these are passed through lime-water, the former is appropriated, and the latter can be collected. The *Formic Acid* of the stated specific gravity has pungent odour like acetic acid, forms barytes, lime, magnesia, etc., in crystal salts; by sulphuric acid is resolved into water and carbonic oxide, or carbonic acid and water by heating with peroxide of mercury. *Acetic Acid* of A 1. × W 1. is volatile, pungent, refreshing, appropriates essential oils and resins; forms the salts named *ascetates*, which by sulphuric acid are decomposed, the *acetic* acid evolving. The *Pyro-acetic* spirit is inflammable, volatile, with a peculiar odour, and miscible with alcohol, ether, or water. *Tartaric Acid* forms the salts named *Tartrates*, and many of these are insoluble in water, yet soluble in excess of the acid; with salts of potash the precipitate is bitartrate of potash; and when the acid is in excess, it precipitates by muriate of platinum from a solution neutralised by carbonate of soda, and boils black. The *Lactic Acid* salts are soluble in alcohol, but do not crystallise. Most of the *Citrates* are soluble in water, and lime-water determines the presence of the acid. The *Malate* of lime, as that of lead, is appropriated by hot water. *Benzoic Acid* is readily by alcohol, but by water partially appropriated, and is separated from *Benzoates* by the strong acids; these salts (as the *Succinates*) precipitate *red-brown* the persalts of iron; in carefully neutralised solutions they do not precipitate salts of manganese. *Gallic Acid* precipitates black persalts of iron, is indifferent to gelatine, and by heat pyrogallic acid sublimes. *Camphor* is volatile, the odour aromatic, and is indifferent to water, but appropriated by alcohol; and very similar in these latter properties are the *Margaric Acid* and the *Oleic*. By saponifying vegetable oil with potash, and treating the soap with alcohol, at ·821°, these two acids and stearine are obtained; the oleate of potash is appropriated, and the margarate remains insoluble, and both are decomposed by the strong acids. The margaric has 3·4, the oleic 3·8 per cent. water present. *Glycerine* is a non-fermentative syrupy, very sweet fluid, appropriated by water or alcohol. *Cholesterine*, the basis of urinary calculi, does not saponify with alkalies, is indifferent to water, but appropriated by alcohol. *Urea* is readily appropriated by alcohol and water; its compounds with oxalic and nitric acids are sluggishly appropriated

by water; when an alkali or alkaline earth is exhibited, decomposition ensues, and carbonate of ammonia results. *Uric Acid* is without savour, indifferent to water or alcohol, appropriated by alkalies, which acids precipitate again; also appropriated by diluted nitric acid, and a crimson stain follows careful evaporation. *Sugar*, CHO (7·25), is white, sweet, brittle, inodourous, appropriated by water or alcohol; and when treated with nitric acid, the hydrogen is separated and oxalic acid is formed. *Gum* is indifferent to alcohol; and ether, yet is appropriated by water; and boiling nitric acid, at 1·34, converts it into *Muric Acid*. *Starch* is white, tasteless, brittle, inodourous, formed by boiling-water into a bulky jelly, which by heat is converted into gum, and boiled long in water, with 8 per cent. of diluted sulphuric acid, forms sugar; it is precipitated by sub-acetate of lead, is by iodine detected in its minutest portions, and is indifferent to alcohol, ether, or cold water. *Gluten* is tenacious, without odour, hard and brittle when dry, putrefactive when moist and warm, indifferent to water or ether, but appropriated by hot alcohol. *Tannin* is without colour or odour, but has astringent savour, is appropriated by ether, hot alcohol, and partially by water; with acid it forms compounds; it is precipitated by gelatine, and black by persalts of iron. *Wax* forms with alkalies, soaps, with oils, cerates, is indifferent to water, but appropriated by ether or hot alcohol, that when cold allows it to deposit; and *Spermaceti* much resembles it. *Resins* are brittle, indifferent to water, but appropriated by alcohol, ether, volatile oils, and alkalies in forming soaps, precipitated by acids, and with wax and oils form ointments and plasters. *Fibrin* is without odour or savour, indifferent to water; acetic acid forms it into a bulky jelly, soluble in hot water; and alcohol at 0·81 converts it to adipocire, soluble in ether and alcohol; exhibiting nitric acid at 1·2 forms an acid as nitrogen evolves. *Albumen* has alkaline potency, and coagulates by heat, alcohol, acids, and voltaic circuit: solutions in which it is present obey the exhibiting of prussiate of potash with a little acetic acid corrosive sublimate, tannin, and hypophosphoric acid, but is indifferent to phosphoric or acetic acid. *Volatile* or *Essential Oils* dissolve resins, sulphur, and camphor, are inflammable, very aromatic, volatile, and when dropped on paper and warmed the oil disappears. *Fixed* or *Animal* and *Vegetable* Oils have *Elain* and *Stearine* as their oily fluid, and white solid com-

ponents, both of which are appropriated by hot alcohol, the latter separating when cold, and the former evolving by heating; with alkalies oils form soaps; with ammonia, liniments; and with protoxide of lead, litharge, diachylon; when dropped on paper and warmed leaves a permanent stain.

Hydrogen Gas is colourless, inflammable, supplies a pale blue flame, intensely hot, but with very little light, the product being only water. *Water Vapour*, at 212° F., expands 1698 times its volume at its greatest density 39·4°; it freezes at 32°, boils at 212°, but this diminishes 1° for each 530 feet ascension in the atmosphere; it is ·815 times heavier than atmospheric air, and 1 cubic inch weighs 252·458 grains. *Deutoxide of Hydrogen* is a very powerful bleaching agent, which decomposes at 59°, and explodes when suddenly exposed to a temperature of 212°. *Olefiant Gas*, C^2 H^2, is appropriated by water to 1-8 its volume, when 2 cl. + 1 oe. gas are exhibited to each other, the result is the oily fluid Hydrocarb. Clorine (*see this*). The gas C^4 H^4 at 54° liquefies with spec. grav. ·627, and vapourises at 30°. The *Bicarburet* solidifies at 32°, liquefies with spec. grav. ·850 at 54°, and boils at 186°. The *Sulphuret* is colourless, noisome like rotten eggs, under a pressure of 17 atmospheres liquefies at 50°. Water appropriates equal volume, and the action is like acid, and it precipitates metals, as sulphates, from their solutions. The *Bisulphuret* has a yellow colour, acts as an acid, forming salts. The *Protophosphate* has an odour like garlic, and water appropriates 1-8 its volume. The *Perphosphate* has like odour, but when oxygen or atmospheric air is present, spontaneous combustion ensues.

Name of the Element, and its Combinations.		Form	Colour.	Symbols of the Components, and their Quantities.	Atomic weight.	Specific Gravity Water=1.	Solubility.	Atmospheric Action.	Fusing Temperature.	Colour of Precipitate by Test.	Theoretic Composition of Salts.			Trivial Name
AMMONIUM.....		?	?	Am	4·5									
Hydrate		*ld*	—	Am H O	8·75									
Sulpho Ditto		*cr*	*w*	Am H S	8·75			*v*						
Sulphite	1	*pm*	*w*	Am^2S	13		*w a*	*d*			4	2·125	0·5625†	
	2	*m*	*w*	Am S	8·5									
Hydro Ditto.....		*cr*	*w*	Am H S	8·75		*w*							
Sulphate.....	1	*pm*	*w*	Am S O^2	16·5		*w a*	*d*			5	2·125	3·375	
	2	*cr*	*w*	Am H S O	12·75						9	2·125	2·25†	
Hydrated Ditto.....	1	*cr*	*w*	Am H S O	12·75						5	2·125	2·125†	
	2	*pr*	*w*	Am H^2S O^3	21						5	2·125	2·125†	
Nitrite	1	*pr*	*w*	Am Z O	12									
	2	*m*	*w*	Am Z O^2	16									
Nitrate.....		*pm*	*w*	Am Z O^3	20	1·5785	*w*				8·25	2·125	1·125	
Chloro osmiate	1	*m*	*bk*	Am Cl^2Os	36		*w*							
	2	*m*	*bk*	Am Cl^3Os	45		*w*							
	3	*ld*	*r*	Am Cl Os	27		*w*							
Ditto platinate		*cr*	*or*	Am Cl Pt	26									
Ditto palladiate.....		*pr*	*y*	Am Cl Pd	20						1	1	1†	
Ditto hydrargyrate....	1	*nd*	*y*	Am Cl Mr	39·5		*w*							
	2	*nd*	*y*	Am Cl^2Mr	48·5		*w*							
	3	*pr*	*y*	Am^2Cl Mr	43		*w*							
	4	*pr*	*w*	Am^2Cl^2Mr	52		*w*							
Ditto stannate.....		*pm*	*y*	Am Cl Sn	28		*w*				1	1	1	
Chlorate		*cr*	*w*	Am Cl O^2	21·5		*w*				4·425	2·125		
Muriate.....		*pm*	*y*	Am Cl H	13·75	1·52	*w a*							
Bromide		*pr*	*w*	Am Bm	24·5		*w*							
Bromohydrargyrate...		*pr*	*w*	Am Bm Mr	49·5		*w*							
Bromate.....		*pr*	*w*	Am Bm O^2	32·5		*w*							
Hydro Ditto.....		*sd*	*w*	Am Bm H O^2	32·75		*w*							
Iodide		*pr*	*w*	Am I	36·5		*w*							
Iodate		*pr*	*w*	Am I O^5	48·5		*w*	*d*			15·875	2·125		
Hydro Ditto.....		*gr*	*w*	Am H I O^4	48·75		*w*	*d*			6	2·125		
Fluoride		*cr*	*w*	Am F	9		*w*							

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Hydrofluate	1	*m*	*vi*	Am H F O^2	17·25		*w a*		100°					
	2	*cr*	*w*	Am^2H F O	17·75		*w a*							
Phosphite	1	*m*	*w*	Am P	8·5		*w*				3·5	2·125	2·25†	
	2	*pr*	*w*	Am P^2	12·5		*w*							
	3	*pr*	*w*	Am^2P	13		*w*							
Phosphate	1	*cr*	*bn*	Am P O^3	20·5	1·8	*w*				4·5	2·125	1·6875†	
	2	*pm*	*w*	Am P^2O	16·5						9	2·125	3·375†	
Selenite	1	*pm*	*w*	Am Se	14·5									
	2	*cr*	*w*	Am Se^2	24·5									
	3	*ld*	*w*	Am^2Se	19									
Seleniate		*pm*	*w*	Am Se O^3	26·5									
Arsenite		*gm*	*w*	Am As	14									
Sulpho Ditto		*pr*	*bn*	Am As S	18									
Arseniate	1	*pm*	*w*	Am As O^3	26						7·25	2·125	1·6875†	
	2	*pm*	*w*	Am As^2O	27·5						7·8	10·7	11·3	
Sulpho Ditto	1	*m*	*y*	Am As S O	22			*d*						
	2	*pr*	*y*	Am As S^2O	26									
Soda Ditto Ditto		*pr*	*y*	Am N S^2As	28						6·5	2·125†		
Chromate	1	*cr*	*y*	Am Cr O^2	19·5		*w*				75·5	24·5		
	2	*pr*	*gn*	Am Cr^2O	22·5									
	3	*ld*	*y*	Am Cr^3O	29·5									
Vanadite		*pr*	*w*	Am V O	25·5									
Vanadate		*pr*	*w*	Am V O^2	29·5									
Molybdate	1	*m*	*w*	Am Mo O^2	24·5		*w*	*d*			9	2·125	0·5625†	
	2	*cr*	*w*	Am Mo O^4	32·5									
Sulpho Ditto		*pr*	*gy*	Am Mo S^4	32·5		*w*							
Hyper Ditto Ditto		*pr*	*y*	Am Mo S^5	36·5		*w*							
Tungstate	1	*nd*	*w*	Am W O	16·5		*w*				15·5	2·125	2·25	
	2	*cr*	*w*	Am W^2O	24·5						31	2·125	2·25†	
Sulpho Ditto		*cr*	*r*	Am W S O	20·5		*w*	*d*						
Borate	1	*w*	*w*	Am B O^3	17·5						3	2·125	2·25†	
	2	*pr*	*w*	Am^2B^3O	16						4·5	2·125	2·25†	
	3	*cr*	*w*	Am B^3O	11·5						9	2·25	5†	
	4	*pr*	*w*	Am B^6O	14·5						18	2·25	7·875†	

Fluo Ditto	1	*pr*	*w*	Am B^3F^4	22·5					2	1†		
	2	*cr*	*w*	Am B^2F	11					1	1†		
	3	*cr*	*w*	Am B F	10					1	1·5†		
Carbonate	1	*m*	*w*	$Am^2C\ O^3$	24	0·966	*w*	*v*		2·75	2·125	2·25†	
	2	*pr*	*w*	Am C^2O	14·5					5·5	2·125	2·25†	
	3	*cr*	*w*	Am C O	11·5					4·125	2·125	1·125†	
Bisulpho Ditto		*pr*	*y*	Am C O^2	15·5								
Chloro Ditto		*pr*	*y*	Am C Cl O	20·5		*w*	*d*		6·25	4·25		
Cyanodide		*pr*	*w*	Am C Z	11								
Sulpho Ditto		*pr*	*y*	Am C Z S^2	19								
Hydro-ferro Ditto		*cr*	*g*	Am C Z H Fe	18								
Cyanate		*pm*	*w*	Am C Z O^2	19·25								
Hydro Ditto		*pm*	*w*	Am C Z H O^2	19·5								
Ditto Sulpho Ditto		*m*	*y*	Am C Z S O	19·5								
Ditto Ferro Ditto		*cr*	*y*	Am C Z H Fe	22								
Fulminate		*m*	*y*	Am Fe C Z	11·25								
Antimonite		*pr*	*w*	Am Sb	15·5								
Antimoniate		*pr*	*w*	Am Sb O^3	27·5								
Tellurate		*pr*	*w*	Am Te O^2	24·5								
Sulpho Ditto	1	*cr*	*bn*	Am^2Te S O	29		*w*	*d*					
	2	*cr*	*y*	Am Te S O	24·5		*w*	*d*					
Tantalate				Am Ta O^2	27·5		*w*						
Fluo Ditto		*sl*	*w*	Am Ta^2F^3	48		*w*						
Titaniate		*fk*	*w*	Am Ti O^2	11·5		*w*						
Fluo Ditto		*pr*	*w*	Am Ti^2F^3	24		*w*			1	1·5		
Silicate		*pr*	*w*	Am Si O	10·5		*w*						
Fluo Ditto				Am Si^2F^3	22								
Uraniate		*pr*	*y*	Am U O^2	47·5					28	2·125	1·6375†	
Oxalate	1	*pm*	*w*	Am C O^2	15·5	1·582	*w*			4·5	2·125	2·25U	
	2	*pm*	*w*	Am C^2O	14·5					9	2·125	9 U	
	3	*pm*	*w*	Am C O	11·5								
Acetate	1	*pm*	*w*	Am H C O^3	19·75					6	2·125	7·875†	
	2	*pm*	*w*	Am $H^2C^2O^3$	23			*d*					
Lactate		*pm*	*w*	Am H C^3O^4	29·75			*d*					
Formate		*pm*	*w*	Am H C^2O^3	22·75		*w*	*v*					
Mellate		*cr*	*w*	Am H C^4O^3	28·75								
Tartrate	1	*pm*	*w*	Am $H^2C^4O^5$	37		*w*			·25	2·125†		
	2	*cr*	*w*	$Am^2H^2C^4O^5$	41·5								
	3	*pl*	*w*	Am $H^3C^6O^5$	43·75								
Vinate		*nd*	*w*	Am H C^2O^4	26·75			*ef*					

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Sulpho Ditto		*cr*	*w*	Am H C^2S O^4	30·75		*w*							
Citrate	1	*pm*	*w*	Am $H^6C^4O^6$	42		*w*				6·125	2·125	1·125	
Pyro Ditto				Am $H^3C^2O^3$	23·25									
Malate		*ld*	*w*	Am H C^4O^3	28·75		*w*							
		cr	*w*	Am^2H C^4O^3	33·25			*o*						
Fungate		*cr*	*w*	Am H C O			*w*							
Benzoate	1	*fl*	*w*	Am $H^5C^{14}O^3$	59·7	1·414		*d*			15·5	2·125	1·125	
	2	*pl*	*w*	$Am^2H^{10}C^5O^5$	46·5		*w a*							
Succinate		*cr*	*w*	Am $H^2C^4O^3$	29		*w*				6·25	2·125	2·25	
Mucate	1	*ct*	*w*	Am $H^5C^4O^8$	55·75									
	2	*cr*	*w*	$Am^2H^5C^6O^8$	60·25									
Pyro Ditto		*cr*	*w*	Am $H^{14}C^6O^{10}$	66									
Gallate		*pr*	*w*	Am $H^2C^3O^4$	30·75									
Meconate		*cr*	*w*	Am $H^9C^9O^4$	49·75		*w*				40	42	18 T	
Boletate		*pm*	*w*	Am H C O			*w*							
Kinate		*cr*	*w*	Am $H^4C^5O^4$	36·5									
Camphorate	1	*m*	*w*	Am H^3C^2O	15·25		*w*	*v*			8·25	4·25	2·25	
	2	*cr*	*w*	$Am^2H^3C^2O$	19·75									
Suberate		*pm*	*w*	Am H^4C O^2	16·5		*w*	*d*						
Stearate	1	*cr*	*w*	Am $H^{15}C^{14}O$	54·25									
	2	*sl*	*w*	$Am^2H^{15}C^{14}O$	58·75									
Margarate		*cr*	*w*	Am $H^{13}C^7O$	32·75									
Oleate		*sd*	*y*	Am $H^3C^{14}O$	51·25									
Phocenate		*ld*	*tr*	Am H C O										
Butyrate		*ld*	*tr*	Am $H^{11}C^8O^3$	43·25									
Caproate		*m*	*y*	Am H^6C^4O	22									
Cholesterate		*m*	*y*	Am H C O				*d*						
Pinate		*m*	*y*	Am $H^{12}C^4O^2$	48·5		*al*							
Silvate		*pm*	*w*	Am H C O			*w a*							
Carbazotate		*cr*	*y*	Am $H^2C^5O^5$	46·5		*w*							
Indigotate		*cr*	*y*	Am $Z^1C^{15}O^{10}$	96·5									
Urate		*pr*	*w*	Am Z H^2C O	15·5		*w*							
Pyrurate		*pl*	*w*	Am Z H^2C^2O	18·5		*w*							
Purpurate		*pm*		Am H C O										

Xanthate				Am H C O			*w*						
Sulphonaphthalate	1	*cr*	*w*	Am $H^6C^9S\ O^4$	53		*wa*						
	2	*cr*	*w*	Am $H^6C^9S^2O^4$	57		*wa*						
THORIUM		*sd*	*gy*	Th	15	9·4							Thorina
Oxide	1	*pr*	*w*	Th^2O	34								
	2	*pr*	*y*	ThO	19								
Hydrate		*fk*	*w*	ThHO	19·25								
Sulphite		*sd*	*br*	ThS	19		*nm*						
Sulphate		*pr*	*y*	$ThSO^2$	27								
Potash Ditto		*pr*	*y*	$ThKS^2O^4$	49		*w*						
Nitrate		*pr*	*w*	$ThZO^3$	30·5								
Chloride		*pr*	*y*	ThCl	24								
Chlorate		*pl*	*w*	$ThClO^3$	36								
Bromide		*gm*	*y*	ThBm	35		*w*						
Iodide		*gm*	*y*	ThI	47								
Fluoride		*pr*	*w*	ThF	19·5								
Phosphite		*sd*	*gy*	ThP	19								
Carburet		*pr*	*w*	ThC	18								
Silicet		*sd*	*gy*	ThSi	17								
ZIRCONIUM		*sd*	*bk*	Zr	5·5	4·3							Zirconia
Oxide	1	*pr*	*bn*	Zr^2O	15								
	2	*pr*	*w*	ZrO	9·5								
	3	*pr*	*bn*	Zr^2O^3	23								
Sulphite		*pr*	*bn*	ZrS	9·5		*fl*						
Sulphate	1	*pr*	*w*	Zr^2SO^2	23						5	7·5†	
	2	*nd*	*w*	Zr^3SO^4	36·5						5	11·25†	
	3	*cr*	*w*	ZrSO	13·5						5	3·75	
Potash Ditto	1	*pr*	*w*	Zr^2KF^3	34·5		*al*						
	2	*pr*	*w*	$Zr^3K^2F^5$	59		*al*						
Nitrate		*gn*	*w*	$ZrZO^3$	22		*w*						
Chloride		*nd*	*w*	ZrCl	14·5		*w*						
Muriate		*ld*	*w*	ZrHCl	14·75			*ef*					
Fluoride		*pr*	*w*	ZrF	9·5		*w*						
Potash Ditto		*pr*	*w*	ZrKF	19·5								

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Ammonia Ditto		*pr*	*w*	$ZrAm^2F$	18·5									
Phosphate		*pr*	*w*	$ZrPO^2$	17·5									
Selenite		*pr*	*y*	ZrSe	15·5									
Arsenite		*pr*	*w*	ZrAs	15									
Sulpho Ditto		*pr*	*or*	$ZrAsS^4$	31									
Hypo Ditto Ditto		*pr*	*r*	$ZrAsS^5$	35									
Arseniate		*pr*	*w*	ZrAsO	19									
Sulpho Ditto		*pr*	*or*	ZrAsSO	23									
Ditto Molybdate		*pr*	*bn*	$ZrMoSO^4$	37·5									
Ditto Tungstate		*pr*	*y*	$ZrWSO^2$	25·5			*d*						
Borate		*pr*	*w*	$ZrBO^3$	18·5									
Carburet		*sd*	*gy*	ZrC	8·5									
Carbonate		*pr*	*w*	Zr^2CO^3	26						44·5	53·5†		
Potash Ditto		*ld*	*w*	ZrKCO	22·5									
Ammonia Ditto		*ld*	*w*	$ZrAm^3CO$	26									
Fluosilicate		*cr*	*w*	$ZrSi^2F^3$	23									
Oxalate		*pr*	*w*	$ZrCHO^2$	16·75									
Acetate		*m*	*gy*	$ZrCHO^3$	20·75		*w*							
Benzoate		*pr*	*w*	$ZrC^{14}H^5O^3$	60·75		*w*							
Tartrate		*pr*	*w*	$ZrC^4H^2O^5$	38									
Citrate		*pr*	*w*	$ZrC^4H^6O^6$	31									
Malate		*pr*	*w*	ZrC^4HO^4	56·75		*w*							
Mucate		*pr*	*w*	$ZrC^6H^5O^8$	33·75									
Gallate		*pr*	*w*	$ZrC^3H^7O^4$	32·75									
ALUMINUM		*sd*	*w*	Al	2·25									Alumina
Oxide		*pr*	*y*	Al^2O	8·5	4·200								
Hydrate	1	*pr*	*w*	AlH^2O^2	10·75									
	2	*pr*	*w*	Al^2HO^2	12·75									
Sulphite	1	*pr*	*w*	Al^2S	8·5									
	2	*pr*	*w*	AlS	6·25									
Hypo Ditto		*pr*	*w*	Al^2S^5	24·5									

Sulphate	1	*pl*	*w*	Al S O^2	14·25		*w*				40	40·9		
	2	*pr*	*w*	Al^2S O	12·5									
	3	*pr*	*w*	Al S^2O	14·25		*ac*				5	6·75	10·125†	
	4	*pr*	*w*	Al S O	10·25		*w*				5	2·25	78·75†	
Hypo Ditto		*m*	*w*	Al^2S^5O	28·5									
Potash Ditto	1	*cr*	*w*	Al K S O^2	24·25	1·7109	*w*				20	6·75	28·125	6
	2	*pr*	*w*	Al K S^3O	28·25	1·757	*w al*				11	35·25	10·125	
Ammonia Ditto	1	*cr*	*w*	Al Am^2S O^2	23·25		*w*				21·75	7·125	28·125	
	2	*pr*	*w*	Al Am S O	14·75						33·25	7·125	10·125	
Soda Ditto	1	*cr*	*w*	Al N^2S O^2	26·25	1·6	*w*				20	6·75	28·125	4
	2	*m*	*w*	Al N S O	16·25	1·88	*w*				9	21·75	28·125	
Ferro Ditto	1	*nd*	*w*	Al Fe^2S O^2	28·25						19	7·25	18·675	
	2	*cr*	*w*	Al Fe S O	17·25									
Nitrate	1	*pl*	*w*	Al Z O^3	17·75	1·645	*w*	*d*			9	2·25†		
	2	*pr*	*w*	$Al^2ZH^2O^3$	20·5						6·75	4·5	11·25†	
	3	*pr*	*w*	$Al^3Z^2H^3O^5$	34·5						6·75	6·75	6·75†	
Chloride		*pr*	*w*	Al Cl	11·25		*w*				1	1	3†	
Muriate		*gm*	*w*	Al H Cl	11·5		*w*	*d*			29·8	30	40·2	
Bromide		*cr*	*w*	Al Bm	6·25		*w*							
Iodide		*cr*	*w*	Al I	34·25		*w*							
Fluoride	1	*pr*	*w*	Al^2F	8·5		*w*							
	2	*pr*	*w*	Al F	6·25		*w*							
	3	*pr*	*w*	Al^2F^3	16·5		*w*							
Phosphite		*gm*	*w*	Al P	6·25									
Phosphate	1	*pr*	*w*	Al P O^2	14·25						4·5	2·25	3·9375†	
	2	*pr*	*w*	Al^2P O^2	17·25						4·5	4·5	3·375†	
	3	*gm*	*w*	Al P^2O^2	18·25									
Selenite	1	*pr*	*w*	Al Se	12·25									
	2	*gm*	*w*	Al Se^2	22·25									
Arsenite		*pr*	*w*	Al As	11·75									
Sulpho Ditto		*pr*	*y*	Al As S	15·75									
Arseniate	1	*pr*	*w*	Al As O^2	19·75						7·25	2·25	6·75†	
	2	*pr*	*w*	Al As^2O^2	29·25									
Sulpho Ditto		*pr*	*y*	Al As S O	19·75		*w*							
Chromate		*ld*	*y*	Al Cr O^3	21·25		*w*							
Molybdate		*pr*	*r*	Al Mo O^2	22·25									
Sulpho Ditto		*pr*	*bn*	Al Mo S O^4	34·25									
Hyper Ditto Ditto		*pr*	*r*	Al Mo S O^5	38·25		*w*							
Tungstate		*pr*	*w*	Al W O^2	18·25									
Sulpho Ditto		*sd*	*y*	Al W S O	18·25		*w*	*d*						

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Borate		*pr*	*w*	Al B O^3	15·25									
Fluo Ditto		*cr*	*w*	Al B^2F^4	23·25		*w*							
Carbonate		*cr*	*w*	Al^2C O^3	19·5									
Potash Ditto		*pr*	*w*	Al K C O	19·25		*al*							
Cyanodide		*pr*	*w*	Al C Z	8·75		*w*							
Sulpho Ditto		*cr*	*w*	Al C Z S	12·75									
Ferro Ditto		*pr*	*y*	Al Fe C Z	15·75		*w*	*d*						
Fulminate		*cr*	*y*	Al H C Z O	13		*w*							
Silicate	1	*sd*		Al^2Si O	10·5									
	2	*sd*		Al Si O	8·25									
	3	*sd*		Al^3Si^2O	14·75									
	4	*sd*		Al H Si O	12·5									
	5	*sd*		$Al^3H^2Si^2O^3$	23·25									
	6	*sd*		Al Si^2O	10·25									
	7	*sd*		Al H^2Si^2O	10·75									
	8	*sd*		Al $H^3Si^3O^4$	25									
	9	*sd*		Al Si^4O	14·25									
Fluo Ditto		*g*	*w*	Al Si^2F^3	19·25									
Oxalate		*m*	*y*	Al C O^2	13·25		.				4·5	2·25	3·975†	
Potash Ditto		*gm*	*w*	Al K C O^2	23·25									
Acetate		*cr*	*w*	Al C O^3	17·25	1·245		*d*			6·25	2·25	1·125†	
Lactate		*gm*	*w*	Al H C^3O^4	27·5									
Formate		*gm*	*w*	Al H C^2O^3	20·5									
Mellate		*pr*	*w*	Al H C^4O^3	26·5			*d*						
Tartrate		*gm*	*w*	Al H C^4O^5	34·75		*w*				8·25	2·25	1·125†	
Potash Ditto		*pr*	*w*	Al K $H^2C^4O^5$	44·75									
Carbo Soda Ditto		*pr*	*w*	Al N H C O							6·75	10·5	10·125†	
Citrate	1	*pr*	*w*	Al $H^6C^4O^6$	39·75		*w*							
	2	*pr*	*w*	$Al^2H^6C^4O^6$	42									
Malate		*pr*	*w*	Al H C^4O^4	30·5		*w*							
Fungate		*gm*	*y*	Al H C O										
Mucate		*pr*	*w*	Al $H^5C^6O^8$	53·5									
Succinate		*pm*	*w*	Al $H^2C^4O^3$	26·75									
Benzoate		*cr*	*w*	Al $H^5C^{14}O^3$	57·5			*d*						

Gallate		*pm*	—	Al $H^7C^3O^4$	29							
Camphorate		*pr*	*w*	Al H^3C^2O	13		*wa*					
Suberate		*m*	*y*	Al $H^4C\ O^2$	14·25							
Cholesterate		*pr*	*r*	Al H C O								
Pinate		*pr*	*w*	Al $H^{12}C^{11}O^2$	46·25							
Urate		*pr*	*w*	Al Z H^2C O	13·25							
YTTRIUM		*sl*	*gy*	Y	8	4·237						Yttria
Oxide	1	*pr*	*w*	Y^2O	20							
	2	*pr*	*w*	Y O	12							
Hydrate		*m*	*w*	Y H O	12·25							
Sulphite		*pr*	*gy*	Y S	12							
Sulphate	1	*gn*	*r*	Y S O^2	20	2·79	*w*		5	5·5	2·25†	
	2	*pm*	*w*	Y S^2O	20							
Potash Ditto		*cr*	*w*	Y K S O	26							
Nitrate		*gm*	*w*	Y Z O^3	23·5		*w*	*d*				
Chloride		*pm*	*w*	Y Cl	17		*w*	*d*				
Muriate		*gm*	*w*	Y H Cl	17·25		*w*	*d*	1	1	3	
Fluoride		*pm*	*w*	Y F	12		*w*					
Phosphite		*pr*	*bk*	Y P	12							
Phosphate	1	*fk*	*w*	Y P O^2	20		*w*		4·5	8·25	2·8125†	
	2	*pr*	*w*	Y P^2O^2	24							
Selenite		*pr*	*bk*	Y Se	18							
Arsenite		*pr*	*bk*	Y As	17·5							
Sulpho Ditto		*pr*	*y*	Y As S	21·5							
Arseniate		*pr*	*w*	Y As O^3	29·5							
Sulpho Ditto		*pr*	*y*	Y As S O	25·5		*w*					
Chromate		*pm*	*or*	Y Cr O^3	27		*w*					
Sulpho Molybdate		*pr*	*bk*	Y Mo S O^4	40		*w*					
Ditto Tungstate		*ld*	*y*	Y W S O^2	28		*w a*	*d*				
Borate		*pr*	*w*	Y $B O^3$	21							
Fluo Ditto		*cr*	*w*	Y B^3F^4	29		*w a*					
Chloro Hydrargyrate		*cr*	*w*	Y Cl Mn	42			*d*				
Carbonate		*pr*	*w*	$Y^2C\ O^3$	31				2·75	5·5	1·725†	
Potash Ditto		*pr*	*y*	Y K C O^3	33		*ac*					
Ammonia Ditto		*pr*	*w*	Y $Am^3C\ O^2$	37·5							
Soda Ditto		*pr*	*w*	Y N^2C O	27							
Cyanodide		*pr*	*w*	Y Z C	14·5							

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Ferro Ditto		*pr*	*gy*	Y Z C Fe	21·5									
Fluosilicate		*pr*	*w*	Y Si^2F^3	25·25		*w al*							
Oxalate	1	*pr*	*w*	$Y^2C\ O^2$	27						4·5	11	2·79†	
	2	*pr*	*w*	Y C O^2	19						6·5	5·5	2·25†	
	3	*pr*	*w*	Y C O	15						6	5·5†		
Potash Ditto		*pr*	*w*	Y K C O	25		*w*							
Acetate		*pr*	*r*	Y C O^3	23		*w*				6·25	5·5	3·375†	
Tartrate		*pr*	*w*	Y $H^2C^4O^5$	40·5		*w*				8·25	5·5	1·125†	
Potash Ditto		*pr*	*y*	Y K $H^2C^4O^5$	50·5		*w*							
Succinate		*cr*	*w*	Y $H^2C^4O^3$	32·5		*w*							
Benzoate		*pr*	*w*	Y $H^5C^{14}O^3$	63·25									
GLUCINUM		*pr*	*gy*	Be	4·5		*ac*							Glucina
Oxide	1	*pr*	*gy*	Be^2O	13	2·976	*al*							
	2	*pr*	*gy*	Be O	8·5									
Sulphite		*m*	*gy*	Be S	8·5									
Sulphate	1	*m*	*w*	$Be^3S\ O^2$	25·5		*w*	*d*			5	9·75	3·375†	
	2	*m*	*w*	Be S^2O	16·5						10	3·25	5·625†	
	3	*m*	*w*	$Be^2S\ O$	17						10	9·75	1·125	
	4	*pr*	*w*	Be S O	12·5						5	3·25	3·375	
Nitrate		*pr*	*w*	Be Z O^3	20									
Chloride	1	*pm*	*w*	Be^2Cl	18		*w a*							
	2	*cr*	*w*	Be Cl	13·5		*w a*							
	3	*gm*	*y*	Be Cl^2	22·5		*w a*							
	4	*pr*	*w*	Be^2Cl^3	36		*w a*							
Muriate		*ld*	*y*	Be H Cl	13·75		*w a*							
Bromide		*nd*	*w*	Be Bm	24·5		*w*	*d*						
Iodide		*nd*	*w*	Be I	36·5		*w*	*d*						
Fluoride		*cr*	*w*	Be F	8·5		*w*							
Phosphite		*pr*	*gy*	Be P	8·5		*w*							
Phosphate	1	*pr*	*w*	Be P O^3	20·5									
	2	*pr*	*w*	Be P^2O^3	20·5									

Selenite		*m*	*gy*	Be Se	14·5							
Arsenite		*pr*	*gy*	Be As	14							
Sulpho Ditto		*pr*	*y*	Be As S	18							
Arseniate	1	*pr*	*w*	Be As O^3	26							
	2	*pr*	*w*	Be As^2O^3	30							
Sulpho Ditto		*pr*	*y*	Be As S O	22							
Chromate		*m*	*y*	Be Cr O^3	23·5		*w*					
Sulpho Ditto		*cr*	*or*	Be Cr S O	19·5		*w*					
Ditto Molybdate		*pr*	*bn*	Be Mo S O^4	36·5		*w*					
Ditto Tungstate		*sd*	*y*	Be W S O^2	24·5		*w*					
Chloro Hydrargyrate		*pm*	*w*	Be Cl Mr	38·5		*w*					
Carbonate		*pr*	*w*	Be^2C O^3	24							
Ammonia Ditto		*pr*	*w*	Be Am^2C O	20·5							
Ferrocyanodide		*ld*	*w*	Be Z C Fe	20		*w*					
Silicate	1	*sd*	*w*	Be Si O	10·5							
	2	*sd*	*bn*	Be $Al^2Si^2O^2$	23							
	3	*sd*	*w*	Be^2Si O	14·5							
Fluo Ditto		*m*	*w*	Be Si^2F^3	22		*w*					
Tellurate		*pr*	*gy*	Be Te	12·5							
Oxalate		*ld*	*w*	Be C O^2	15·5		*w*					
Acetate		*pl*	*w*	Be C O^3	19·5		*w*					
Tartrate		*pr*	*w*	Be $H^2C^4O^5$	37		*w*					
Citrate		*gm*	*y*	Be $H^6C^4O^6$	42							
Succinate		*pr*	*w*	Be $H^2C^4O^3$	29		*w*					
Benzoate		*fk*	*w*	Be $H^5C^{14}O^3$	59·75							
MAGNESIUM		*fk*	*w*	Mg	3							
Oxide	1	*pr*	*w*	Mg^2O	10							
	2	*pr*	*w*	Mg O	7							
Hydrate		*ld*	*w*	Mg H O	7·25							
Sulpho Ditto		*ld*	*y*	Mg H S	7·25		*w*	*d*				
Sulphite	1	*pr*	*w*	Mg^2S	10	1·38	*w*	*d*	4	2·5	4·5†	
	2	*pr*	*w*	Mg S	7							
Hypo Ditto		*pr*	*w*	Mg^2S^5	26							
Ammonia Ditto		*cr*	*w*	Mg Am S	11·5	1·696	*w*	*ef*				
Sulphate	1	*pm*	*w*	Mg S O^2	15	1·664	*w*	*ef*	38	18	14	
	2	*pr*	*w*	Mg S^2O	15				5	2·5	7·875†	
Hypo Ditto		*pr*	*w*	Mg^2S^5O	30		*w*		9	2·5	6·75†	

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Potash Ditto		*cr*	*w*	Mg K S O	21	2·112	*w*				11	7·5	7·875†	
Ammonia Ditto		*pm*	*w*	Mg Am S O	20	1·721	*w*				7·5	7·125	7·875†	
Soda Ditto		*pm*	*w*	Mg N S O	17		*w*				9	7·5	6·75	
Nitrate		*nd*	*w*	Mg Z O^3	18	1·736					6·75	2·5	6·75	
Ammonia Ditto		*pm*	*w*	Mg Am Z O^3	23			*ef*						
Calcareo Ditto		*pr*	*w*	Mg C Z O^3	23·5		*w*	*d*			1	1	6	
Chloride		*nd*	*w*	Mg Cl	12	1·6		*d*			57	43		
Chlorate		*m*	*w*	Mg Cl O^3	25		*w*				9·5	2·5	2·25†	
Chloro-aurate		*pm*	*y*	Mg Cl^3Au	46·5		*w*				3	1	12	
Ditto platinate		*pl*	*y*	Mg Cl Pt	24·25		*w*				1	1	6	
Ditto palladiate		*cr*	*bn*	Mg Cl Pd	18·5		*w*							
Ditto hydrargyrate	1	*pm*	*w*	Mg Cl^3Mr	55		*w a*				1	3	5	
	2	*pm*	*w*	Mg Cl Mr	37		*w a*	*d*			1	1	6	
Bromide		*pr*	*w*	Mg Bm	23		*w*	*d*						
Iodide		*m*	*w*	Mg I	35		*w*	*d*			15·65	2·5		
Fluoride		*pr*	*w*	Mg F	7									
Phosphite		*pr*	*w*	Mg P	7						3·5	2·5	3·375†	
Ammonia Ditto		*pm*	*w*	Mg Am P	11·5		*w*							
Phosphate	1	*pm*	*w*	Mg P O^3	19	1·55	*w*	*ef*			4·5	2·5	7·875†	
	2	*pm*	*w*	Mg P^2O	15						4·5	5	1·125†	
Ammonia Ditto		*pr*	*w*	Mg Am^2PO	20		*w*				33	33	34	
Selenite	1	*pl*	*w*	Mg Se	13									
	2	*pr*	*w*	Mg Se^2	23									
Arsenite		*m*	*br*	Mg As	12·5									
Sulpho Ditto		*m*	*y*	Mg As S	16·5									
Arseniate	1	*pm*	*w*	Mg As O^3	24·5		*w*				7·75	2·5	9†	
	2	*m*	*y*	Mg As^2O	26		*w*							
Sulpho Ditto	1	*m*	*y*	Mg As S O	20·5									
	2	*cr*	*y*	Mg As S^2 O	24·5									
Ammonia Ditto		*cr*	*y*	Mg Am^2AsSO	29·5		*w*	*d*						
Chromate		*pm*	*y*	Mg Cr O^2	18		*w*				6·5	2·5	2·25†	
Potash Ditto		*pr*	*y*	Mg K Cr O	28		*w*				12·5	9	2·25†	
Molybdate		*m*	*w*	Mg Mo O^2	23		*w*				9	2·5	4·5†	
Sulpho Ditto		*pr*	*bn*	Mg Mo S O^4	35									

Hyper Ditto Ditto.....		*pr*	*r*	Mg Mo S O^5	39							
Tungstate.....		*sc*	*w*	Mg W O^2	19		*w*					
Sulpho Ditto.....		*m*	*y*	Mg W S O	19		*w a*	*d*				
Borate	1	*cr*	*w*	Mg B O^3	16	2·566			6	2·5†		
	2	*cr*	*w*	Mg B^2O	9							
Fluo Ditto.....		*pm*	*w*	Mg B^2F^3	18·5		*w*					
Carbonate.....	1	*pr*	*w*	Mg^2C O^3	21		*v*		35·7	44·6	19·7	
	2	*cr*	*w*	Mg $H^3C^2O^3$	21·75		*w*	*ef*	2·75	2·5	3·375†	
	3	*m*	*w*	$Mg^4H^4C^3O^7$	50		*w*		8·25	10	4·5†	
Bisulpho Ditto.....		*pr*	*y*	Mg C S^2O	18		*w*					
Potash Ditto		*cr*	*w*	Mg K C S O	24		*w*		11·5	10·5	10·125†	
Ammonia Ditto		*cr*	*w*	Mg Am C S O	18·5				32	18	50	
Calcareo Ditto		*pr*	*w*	Mg Ca C S O	19							
Cyanodide		*pr*	*w*	Mg C Z	9·5		*w*					
Sulpho Ditto		*pr*	*w*	Mg C Z S	13·5		*w*	*d*				
Ferro Ditto		*ld*	*y*	Mg C Z Fe	16·5		*w*	*d*				
Fulminate	1	*pm*	*y*	Mg H C Z O	13·75		*w a*					
	2	*pm*	*r*	Mg H C Z^2O	17·25		*w a*					
Sulpho tellurate.....		*cr*	*y*	Me Te S O	19		*w a*					
Fluo tantalate		*pr*	*w*	Mg Ta F	46·5		*w*					
Ditto titaniate.....		*cr*	*w*	Mg Ti F	22·5		*w*					
Silicate.....	1	*sd*		Mg Si O	9							
	2	*sd*		$Mg^3H^2Si^2O^2$	21·5							
	3	*sd*		$Mg^2H^2Si^3O^2$	20·5							
	4	*sd*	*varying*	Mg Si^2O	11							
	5	*sd*		Mg H Si^2O	11·25							
	6	*sd*		Mg Si^3O	13							
	7	*sd*		Mg $H^4Si^3O^4$	14							
Fluo Ditto.....		*m*	*y*	Mg Si^2F^3	20·5		*w*					
Oxalate.....	1	*pr*	*w*	Mg C O^2	14				4·5	2·5	2·25†	
	2	*pr*	*w*	Mg C O	10				9	2·5	7·875†	
Ammonia Ditto.....		*ct*	*w*	Mg Am C O	14·5		*w*		58	25	8	9†
Acetate.....		*gm*	*w*	Mg H C O^3	18·25	1·378	*w*	*d*	6·25	2·5	5·625†	
Lactate.....		*gm*	*w*	Mg H C^3O^4	28·25							
Formate.....		*nd*	*w*	Mg H C^2O^3	21·25							
Tartrate.....	1	*pr*	*w*	Mg $H^2C^6O^5$	35·5		*w*		8·25	2·5	2·25†	
	2	*cr*	*w*	$Mg^2H^2C^6O^5$	38·5		*w*		16·5	2·5	1·125†	
Potash Ditto		*cr*	*w*	Mg K $H^2C^3O^5$	45·5		*w*		22·5	21·5	4·5	
Vinate.....		*pr*	*w*	Mg H C^2O^4	25·25							
Citrate.....		*m*	*w*	Mg $H^6C^4O^6$	40·5		*w*		66·6	33·34		

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Malate		*cr*	*w*	Mg H C^4O^4	31·25		*w*							
Mucate	1	*pr*	*w*	Mg $H^5C^6O^8$	54·25		*w*							
	2	*pr*	*w*	$Mg^2H^5C^6O^8$	57·25		*w*							
Succinate		*m*	*w*	Mg $H^2C^4O^3$	27·5		*w*	*d*						
Benzoate		*cr*	*w*	Mg $H^5C^{14}O^3$	58·25		*w*							
Gallate		*pr*	*w*	Mg $H^7C^3O^4$	29·75		*w*							
Kinate		*cr*	*w*	Mg $H^4C^5O^4$	35		*w*							
Meconate		*nd*	*w*	Mg H C^9O^4	48·25		*w*							
Camphorate		*pl*	*w*	Mg H^3C^2O	13·75		*w*				12·5	3·3†		
Suberate		*pr*	*w*	Mg H^4C O^2	15		*w*	*d*						
Oleate		*m*	*w*	Mg $H^3C^{14}O$	49·75									
Cholesterate		*pr*	*w*	Mg H C O										
Pinate		*pr*	*w*	Mg $H^{12}C^{11}O^2$	47		*w*							
Silvate		*gm*	*w*	Mg H C O										
Carbazotate		*pr*	*y*	Mg $Z^2C^5O^5$	45		*w*							
Urate		*pr*	*w*	Mg Z H^2C O	14									
Aspartate		*pr*	*w*	Mg H C O										
Nitro saccharate		*pr*	*w*	Mg Z C O										
Sulpho naphthalate		*pr*	*w*	Mg H^6C^9S O^4	51·5									
CALCIUM		*pr*	*w*	Ca	5									Lime
Oxide	1	*pr*	*w*	Ca^2O	14									
	2	*pr*	*w*	Ca O	9									
Hydrate		*cr*	*w*	Ca H O	9·25	2·322			51°		5	3·25	2·25†	
Sulpho Ditto		*cr*	*w*	Ca H S	9·25									
Sulphite	1	*pm*	*r*	Ca^2S	14		*w*				4	3·5	2·25†	
	2	*pr*	*y*	Ca S	9		*w*	*ef*			54·29	25·71		
	3	*pm*	*y*	Ca^2S^3	22									
Hypo Ditto		*cr*	*w*	Ca^2S^5	30		*w*				5	3·5	6·75	
Sulphate	1	*pm*	*w*	Ca S O^2	17		*w*				45·8	33·2	21	
	2	*pr*	*y*	Ca S^2O^2	21									
	3	*pl*	*w*	Ca S O	13									

Hypo Ditto		*cr*	*w*	Ca S^2O^5	33					9	3·5	4·5†
Soda Ditto		*cr*	*w*	Ca N S O	19					9	8·5	
Hydro carbo. Ditto		*pr*	*w*	Ca H^2S O	19·5							
Nitrate	1	*nd*	*w*	Ca Z O^3	20·5	1·6207	*w a*			6·75	3·5	3·375†
	2	*m*	*w*	Ca H^2Z O^6	33					6·75	3·5	6·75†
Chloride		*pm*	*w*	Ca Cl	14	1·76				1	1	7†
Ammonia Ditto		*pr*	*w*	Ca Am^4Cl	32							
Chlorate		*m*	*w*	Ca Cl O^3	26		*w*	*d*		9·5	3·5	2·25†
Ditto aurate		*pm*	*y*	Ca Cl Am	30·5		*w*	*d*		3	1	6†
Ditto platinate		*pm*	*y*	Ca Cl Pt	26·25		*w*					
Ditto palladiate		*pm*	*bn*	Ca Cl Pd	20·5		*w a*	*d*				
Ditto hydrargyrate	1	*cr*	*w*	Ca Cl^5Mr	75		*w*			5	8	1
	2	*cr*	*w*	Ca Cl Mr	39		*w*			2	1	1
Ditto stannate		*pr*	*w*	Ca Cl Sn	28·5							
Muriate		*ld*	*y*	Ca H Cl O	18·25	1·76	*w*			48·1	51·9	
Bromide		*m*	*w*	Ca Bm	25		*w*	*d*		1	1	
Iodide		*pm*	*w*	Ca I	37		*w*	*d*		20·5	3·5	3†
Iodate		*pm*	*w*	Ca I O^3	49		*w*	*d*		20·75	3·5†	
Fluoride		*pm*	*bk*	Ca F	9·5	3·15			51°	1·125	3·5	
Phosphite	1	*pr*	*w*	Ca P	9					3·5	3·5	1·125†
	2	*pr*	*w*	Ca P^2	13		*w*					
Phosphate	1	*pm*	*w*	Ca^4P O^3	36	3·0						
	2	*pr*	*w*	Ca P^2O^3	25		*w*					
	3	*m*	*w*	$Ca^2P^2O^3$	30		*a c*		378°	4·5	3·75†	
	4	*ct*	*w*	Ca P O	13					4·5	3·5†	
	5	*pr*	*w*	$Ca^2P^2O^4$	38					6·75	3·5†	
Selenite	1	*pr*	*w*	Ca Se	15							
	2	*sd*	*w*	Ca Se^2	25							
Arsenite		*pr*	*w*	Ca As	14·5					67	33	
Sulpho Ditto		*pr*	*r*	Ca As S^4	30·5							
Hypo Ditto Ditto		*pr*	*r*	Ca As S^5	34·5							
Arseniate	1	*cr*	*w*	$Ca^4As^4O^7$	86							
	2	*pr*	*w*	$Ca^4H^{12}As^4O^7$	113							
	3	*cr*	*w*	Ca H As O	18·75		*a c*			7·5	3·5	3·375†
Sulpho Ditto		*m*	*y*	Ca H As S^2	22·75		*w*	*d*				
Chromate		*pl*	*y*	Ca Cr O^3	24		*w*			6·5	3·5†	
Molybdate		*pr*	*w*	Ca Mo O^2	25							
Sulpho Ditto	1	*cr*	*r*	Ca Mo S O^4	37		*w*					
	2	*cr*	*r*	Ca Mo S^2O^4	41		*w*					
Hyper Ditto Ditto		*pr*	*w*	Ca Mo S O^5	41							

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Tungstate		*pm*	*w*	Ca W^3O^2	37	6·0					13·5	3·5†		
Sulpho Ditto		*m*	*y*	Ca W S^2	21		*w a*	*d*			80·6	19·4		
Borate		*pr*	*w*	Ca B O^3	18		*w*							
Fluo Ditto		*m*	*w*	Ca B^2F^3	20·5		*w*							
Carbonate	1	*cr*	*w*	Ca^2C O^3	25	2·717					2·75	3·5†		
	2	*m*	*w*	Ca C^2O	15									
Bisulpho Ditto		*cr*	*y*	Ca C S^2O	20		*w*	*d*						
Ammonia Ditto		*ld*	—	Ca Am^2C O	21									
Cyanodide		*gn*	*w*	Ca C Z	11·5		*w*							
Sulpho Ditto		*cr*	*w*	Ca C Z S	15·5		*al*	*d*						
Ferro Dittto		*gn*	*y*	Ca C Z Fe	18·5	1·005	*w*				2	1	12†	
Cyanate		*ld*	*w*	Ca H C Z O^2	19·75		*w*							
Fulminate		*pl*	*y*	Ca H C Z O	15·76		*w*							
Antimonite		*pr*	*w*	Ca Sb	16									
Antimoniate		*pr*	*w*	Ca Sb O^3	28		*w*							
Tellurate		*sd*	*y*	Ca Te O^2	21									
Sulpho Ditto		*sd*	*y*	Ca Te S	17		*w*							
Tantalate		*pr*	*w*	Ca Ta O^2	28									
Fluo Ditto		*pr*	*w*	Ca Ta F	24·5		*w*							
Ditto titaniate		*pm*	*w*	Ca Ti F^2	17		*w*							
Silicate	1	*sd*	*w*	Ca Si O	11									
	2	*sd*	*w*	Ca^2Si^2O	18									
	3	*sd*	*w*	Ca Si^2O	13									
	4	*sd*	*w*	Ca^2Si O	16									
Potash Ditto		*pr*	*w*	Ca K Si O	21		*w*							
Fluo Ditto		*cr*	*w*	Ca Si F O	15·5		*al*							
Uraniate		*pr*	*y*	Ca U O^2	48									
Manganate		*cr*	*w*	Ca Mn O^2	20		*w*							
Oxalate		*pr*	*w*	Ca C O^2	16						4·5	3·5	2·25†	
Croconate		*pr*	*y*	Ca H C^5O^4	36									
Acetate	1	*nd*	*w*	Ca H C O^3	20·25	1·005	*w*				6·25	3·5	6·75	
	2	*cr*	*w*	Ca $H^2C^2O^3$	23·5									
Lactate		*gm*	*w*	Ca H C^3O^4	30·25		*w*							
Formate		*cr*	*w*	Ca H C^2O^3	23·25			*ef*						

Mellate		*cr*	*w*	Ca H C^4O^3	29·25				6·5	3·5	2·25†
Tartrate	1	*pr*	*w*	Ca $H^2C^4O^5$	37·5				8·25	3·5	4·5†
	2	*pr*	*w*	$Ca^2H^2C^4O^5$	42·5	*w*					
Pyro Ditto		*pr*	*w*	Ca H C O							
Potash Ditto		*cr*	*w*	Ca K $H^3C^4O^5$	47·5	*w*					
Ammonia Ditto		*pr*	*w*	CaAm$H^2C^4O^5$	42	*w*	*ef*		10·375	14·250	2·25
Soda Ditto		*m*	*w*	Ca N $H^2C^4O^5$	43·5	*w*					
Chlorovinite		*pm*	—	Ca Cl H C O	21·25	*w*	*ef*	400°			
Vinate		*nd*	*w*	Ca H C^2O^4	27·25	*ac*					
Sulpho Ditto		*pr*	*w*	Ca H C^2S O^4	31·25	*w a*					
Chloro Ditto		*pr*	*w*	Ca Cl H C^2O^4	36·25						
Citrate	1	*pr*	*w*	Ca $H^6C^4O^6$	42·5				7·25	3·5†	
	2	*pr*	*w*	Ca $H^3C^2O^3$	23·75	*w*			66	34	30
Pyro Ditto		*pr*	*w*	Ca $H^{10}C^6O^9$	61·5				7	3·5	4.5†
Malate	1	*cr*	*w*	Ca H C^4O^4	33·25	*w*					
	2	*pr*	*w*	Ca^2H C^4O^4	38·25						
	3	*cr*	*w*	Ca $H^2C^3O^5$	26·5				17	3·5	6·75†
Pyro Ditto		*pr*	*w*	Ca H C^2O^5	31·25						
Potash Ditto		*pr*	*w*	Ca K H C^4O^4	43·25						
Ammonia Ditto		*cr*	*w*	CaAm^{2}HC^{4}O^4	37·75						
Soda Ditto		*pr*	*w*	Ca N H C^4O^4	39·75						
Fungate		*pl*	*w*	Ca H C O		*w*					
Mucate		*pr*	*w*	Ca $H^5C^6O^8$	56·25						
Pyro Ditto		*pr*	*w*	Ca^2 $H^5C^6O^8$	61·25	*w*					
Succinate		*cr*	*w*	Ca $H^2C^4O^3$	29·5	*w*					
Benzoate		*cr*	*w*	Ca $H^5C^{14}O^3$	60·25	*w*					
Gallate		*pr*	*w*	Ca $H^7C^6O^4$	27·75	*w*			83	17	
Kinate		*pl*	*w*	Ca $H^4C^5O^4$	37	*w*					
Meconate		*pm*	*w*	Ca $H^9C^9O^4$	50·25				2·875	3·5	2·25†
Boletate		*pm*	*w*	Ca H C O		*w*					
Camphorate		*pl*	*w*	Ca H^3C^2O	15·75	*w*	*ef*		13·375	3·5	9†
Suberate		*m*	*w*	Ca H^4C O^2	17						
Stearate		*pr*	*w*	Ca $H^{15}C^{11}O$	54·75						
Margarate		*pr*	*w*	Ca $H^{13}C^7O$	33·25						
Oleate		*pr*	*w*	Ca $H^3C^{14}O$	51·75						
Phocenate		*pm*	*w*	Ca H C O							
Butyrate		*pr*	*w*	Ca $H^{11}C^3O^3$	43·75	*w*					
Baryto Ditto		*pr*	*w*	GaBa$H^{11}C^3O^3$	61·25	*w*					
Caproate		*pl*	*w*	Ca H^6C^4O	22·5	*w*					
Cholesterate		*pr*	*w*	Ca H C O							

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Pinate		*pr*	*w*	Ca $H^{12}C^{11}O^{2}$	49		*a*							
Silvate		*fk*	*w*	Ca H C O			*w a*							
Carbazotate		*pm*	*w*	Ca Z $H^{2}C^{5}O^{5}$	47									
Urate	1	*pr*	*w*	Ca Z $H^{2}C$ O	16									
	2	*pm*	*w*	Ca Z $H^{2}C$ O	21									
Pyrurate		*cr*	*w*	Ca Z $H^{2}C^{2}O$	24									
Purpurate		*nd*	*w*	Ca $H^{3}C^{2}O$	15·75		*w*							
Moroxylate		*nd*	*w*	Ca H C O			*w*							
Aspartate		*qm*	*y*	Ca H C O										
Sulpho naphthalate		*pr*	*w*	Ca $H^{6}C^{9}SO^{4}$	53·5		*a*							
Sinapate		*pr*	*w*	Ca Z $H^{9}C^{5}O^{4}$	35·75		*s*							
STRONTIUM		*sd*	*a*	Sr	11									
Oxide	1	*pr*	*gy*	$Sr^{2}O$	26		*w*							
	2	*pr*	*gy*	Sr O	15									
	3	*pr*	*w*	$Sr O^{2}$	19									
Hydrate		*pr*	*w*	Sr H O	15·25									
Sulpho Ditto		*pm*	*w*	Sr H S^{2}	19·25				250°					
Sulphite	1	*cr*	*w*	$Sr^{2}S$	26		*w*				4	6·5†		
	2	*pl*	*w*	Sr S	15									
Hypo Ditto		*pr*	*w*	Sr S^{5}	31			*ef*			10	6·5	5·625†	
Sulphate	1	*pr*	*w*	Sr S O^{2}	23	3·86	*w ac*				10	6·5	5·625†	
	2	*pm*	*w*	Sr $S^{2}O$	23		*w*							
Hypo Ditto		*pr*	*w*	Sr $S^{2}O^{5}$	39		*w*				9	6·5	4·5†	
Nitrate		*pm*	*w*	Sr Z O^{3}	26·5	3·006	*w*				6·75	6·5†		
Hydrated Ditto		*pr*	*w*	Sr H Z O^{3}	26·75						6·75	6·5	4·5†	
Chloride		*th*	*w*	Sr Cl	20	2·83	*w*				9·5	6·5		
Ammonia Ditto		*pr*	*w*	Sr $Am^{4}Cl$	38						4·5	6·5		
Chloro aurate		*pm*	*y*	Sr Cl Au	36·5		*w*							
Ditto platinate		*pm*	*y*	Sr Cl Pt	32·25		*w*				1	1	8†	
Ditto hydrargyrate		*nd*	*w*	Sr Cl Mr	45		*w*							
Chlorate		*nd*	*w*	Sr Cl O^{3}	32		*w*				9·5	6·5	5·625†	

Bromide		*cr*	*w*	Sr Bm	31		*w*				1	1	1†
Iodide		*m*	*w*	Sr I	43		*w*				20·5	6·5	
Iodate		*pm*	*w*	Sr I O^3	55		*w*				20·75	6·5†	
Fluoride		*pr*	*w*	Sr F	15·5						1	1	
Phosphite	1	*m*	*w*	Sr P	15		*w*						
	2	*pr*	*w*	Sr P^2	19								
Hypo Ditto		*pr*	*w*	Sr P^5	31		*w*						
Phosphate	1	*pr*	*w*	Sr P O^3	27						4·5	6·5†	
	2	*pr*	*w*	Sr P^2O^3	31						36·56	64·44†	
Selenite		*pr*	*w*	Sr Se	21		*w*						
Arsenite		*m*	*w*	Sr As	20·5		*w*						
Sulpho Ditto		*pr*	*br*	Sr As S^4	36·5		*w*						
Hypo Ditto Ditto		*pr*	*r*	Sr As S^5	40·5		*w*						
Arseniate	1	*pr*	*w*	Sr As O^3	32·5						7·25	6·5	9†
	2	*pr*	*w*	Sr As^2O^3	42								
Sulpho Ditto		*pr*	*y*	Sr As S O^3	36·5								
Chromate	1	*pr*	*y*	Sr Cr O^2	26								
	2	*pr*	*or*	Sr Cr^2O	29						6·5	6·5†	
Molybdate		*pr*	*w*	Sr Mo O^2	31								
Sulpho Ditto		*cr*	*r*	Sr Mo S O^4	43								
Hyper Ditto Ditto		*pr*	*y*	Sr Mo S O^5	47								
Tungstate		*pr*	*w*	Sr W O^2	27								
Sulpho Ditto		*ld*	*y*	Sr W S O	27								
Borate		*pr*	*w*	Sr B O^3	24		*w*						
Fluo Ditto		*sd*	*w*	Sr B^2 F^3	26·5								
Carbonate		*pr*	*w*	Sr^2C O^3	37	3·66	*w*		226°		2·75	6·5†	
Bisulpho Ditto		*m*	*y*	Sr C S^2C	26		*w*				29·7	70·3	
Cyanodide		*pm*	*w*	Sr C Z	17·5		*w*						
Sulpho Ditto		*m*	*w*	Sr C Z S	21·5		*w*	*d*					
Ferro Ditto		*m*	*y*	Sr C Z Fe	24·5		*w*						
Fulminate		*cr*	*w*	Sr H C Z O	21·75		*w*						
Tellurate		*pr*	*w*	Sr Te O^2	27								
Sulpho Ditto		*cr*	*y*	Sr T S O	27		*w ac*						
Silicate		*m*	*gy*	Sr Si O	17		*w*						
Fluo Ditto		*pr*	*w*	Sr Si^2F^3	28·5		*w*						
Manganate	1	*pr*	*gn*	Sr Mn O^2	26								
	2	*m*	*gn*	Sr Mn^2O^3	37								
Oxalate	1	*pr*	*w*	Sr C O^2	22		*w*				4·5	6·5	2·25†
	2	*pm*	*w*	Sr C^2O^2	25		*w*				9	6·5	
Acetate		*pm*	*w*	Sr H C O^3	22·25		*w*				6·25	6·5	1·125†

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Lactate		*gm*	*y*	Sr H C^3O^4	36·25		*w*							
Formate		*pr*	*w*	Sr H C^2O^3	29·25						4·625	6·5	2·5†	
Mellate		*pr*	*w*	Sr H C^4O^3	35·25		*w ac*							
Tartrate		*pm*	*w*	Sr $H^2C^4O^3$	43·5		*w*				8·25	6·5	3·375†	
Potash Ditto		*pr*	*w*	Sr K $H^2C^4O^5$	53·5						40	30	3	
Vinate		*fk*	*w*	Sr H C^2O^4	33·25		*w*							
Citrate		*cr*	*w*	Sr $H^6C^4O^6$	48·5		*w*							
Malate	1	*gn*	*w*	Sr H C^4O^4	39·25		*w*							
	2	*gn*	*w*	Sr^2H C^4O^4	50·25									
Mucate	1	*fk*	*w*	Sr $H^5C^6O^8$	62·25		*w*							
	2	*pr*	*w*	$Sr^2H^5C^6O^8$	73·25		*w*							
Succinate		*cr*	*w*	Sr $H^2C^4O^3$	35·5		*w*							
Benzoate		*pr*	*w*	Sr $H^5C^{14}O^3$	66·25		*w*							
Gallate		*pr*	*w*	Sr $H^7C^8O^4$	37·75									
Camphorate		*pr*	*w*	Sr H^3C^2O	21·75		*w*							
Suberate		*ct*	*w*	Sr H^4C O^2	23						65·48	34·52		
Stearate		*pr*	*w*	Sr $H^{15}C^{14}O$	60·75									
Margarate		*pr*	*w*	Sr $H^{13}C^7O$	39·25									
Oleate		*pr*	*w*	Sr $H^3C^{14}O$	57·75									
Phocenate		*pr*	*w*	Sr H C O										
Butyrate		*pr*	*w*	Sr $H^{11}C^8O^3$	49·25		*w*							
Caproate		*pl*	*y*	Sr H^6C^4O	28·25									
Caprate		*pr*	*w*	Sr $H^{10}C^6O$	35·5		*w*							
Cholesterate		*pr*	*or*	Sr H C O										
Urate		*pr*	*w*	Sr Z H^2C O	22		*w*							
Sulpho naphthalate		*cr*	*w*	Sr H^6C^9S O^4	59·5		*w a*							
Sinapate		*cr*	*w*	Sr Z H^9C^3 O^4	41·75									
BARIUM		*sd*	*gy*	Ba	17·5									
Oxide	1	*pr*	*gy*	Ba^2O	39	4·00								
	2	*pr*	*w*	Ba O	21·5		*w*							

Hydrate	1	*pr*	*y*	Ba H O^2	25·75		*w*						
	2	*pr*	*y*	Ba H^5O^6	42·75								
	3	*pr*	*y*	Ba $H^{20}O^{21}$	106·25								
Sulpho Ditto		*pm*	*w*	Ba H S	21·75								
Sulphite	1	*pr*	*w*	Ba^2S	39	1·694					8	9·5	
	2	*nd*	*w*	Ba S	21·5						4	9·5†	
Hypo Ditto		*pr*	*w*	Ba S^5	37·5						10	9·5	
Sulphate	1	*cr*	*w*	Ba S O^2	29·5						5	9·75	
	2	*pr*	*w*	Ba S^2O^2	33·5						5	9·5†	
	3	*pr*	*w*	$Ba^2H^2S^2O^6$	43						9	9·5	2·25†
	4	*sd*	*w*	Ba $H^4S^2O^6$	29·5						9	9·5	4·5†
Vegeto Ditto		*pr*	*y*	Ba H C S O	28·75								
Nitrate		*pm*	*bn*	Ba Z O^3	33	2·9	*w*				6·75	9·5†	
Chloride		*tb*	*w*	Ba Cl	26·5	2·83	*w*				4·5	8·75	
Chloro aurate		*pm*	*y*	Ba Cl Au	43		*w*				1	1	2
Ditto platinate		*pm*	*y*	Ba Cl Pt	38·75		*w a*				1	1	4
Ditto palladiate		*cr*	*w*	Ba Cl Pd	33		*w*						
Ditto hydrargyrate		*pm*	*y*	Ba Cl^5Me	51			*d*			1	1·5	3
Ditto stannate		*pm*	*w*	Ba Cl Sn	41								
Chlorate		*pm*	*w*	Ba Cl O^3	38·5						9·5	9·5	2·25†
Bromide		*cr*	*w*	Ba Bm	37·5						1	1	1
Bromate		*cr*	*w*	Ba Bm O^3	49·5						15	9·5	
Iodide		*pm*	*w*	Ba I	49·5			*d*			20·5	9·75†	
Iodate		*pm*	*w*	Ba I O^3	61·5						20·75	9·5†	
Fluoride		*pr*	*w*	Ba F	22						1	1	2
Fluate		*pr*	*w*	Ba F O	26								
Phosphite	1	*pr*	*br*	Ba^2P	39		*w*				3·5	9·5	1·125†
	2	*pr*	*gy*	Ba P	21·5								
	3	*pr*	*w*	Ba^4P^3	82								
	4	*pr*	*w*	Ba P^2	25·5		*w*				7	9·5	2·25†
Phosphate	1	*pr*	*w*	Ba P O^3	33·5								
	2	*pr*	*w*	Ba P^2O^3	37·5	1·2867	*w*		35°		7	9·5	4·5
	3	*pm*	*w*	Ba P O	25·5						4·5	9·5†	
Nitro Ditto		*gr*	*w*	Ba Z P O	29						20·75	3·5	
Selenite	1	*pr*	*w*	Ba Se	27·5		*ac*						
	2	*pr*	*w*	Ba Se^2	37·5		*w*						
Arsenite		*pr*	*w*	Ba As	27								
Sulpho Ditto		*pr*	*bn*	Ba As S^4	43		*w*						
Hypo Ditto Ditto		*pr*	*r*	Ba As S^5	47						4		

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Arseniate	1	*pr*	*w*	Ba As O^3	39						42·94	57·6		
	2	*pr*	*w*	Ba As^2O^3	48·5						7·25	9·5	2·25†	
	3	*pr*	*w*	Ba As^2O^3	48·5						7·25	14·25†		
	4	*pr*	*w*	Ba H^1As^2O	41·5						7·25	19	2·8125†	
Sulpho Ditto	1	*pr*	*y*	Ba As S O	35									
	2	*pr*	*y*	Ba As S^2O	39									
Chromate		*pr*	*y*	Ba Cr O^2	32·5						6·5	9·5†		
Molybdate		*fk*	*w*	Ba Mo O^2	37·5						9	9·5†		
Sulpho Ditto		*cr*	*r*	Ba Mo S O^4	49·5									
Hyper Ditto Ditto		*pr*	*y*	Ba Mo S O^5	53·5									
Tungstate		*pr*	*w*	Ba W O^2	33·5									
Sulpho Ditto		*ct*	*y*	Ba W S O	33·5			*d*						
Borate	1	*pr*	*w*	Ba B O^3	30·5						9	9·5†		
	2	*pr*	*w*	Ba B^2O^3	31·5						13·5	9·5†		
Fluo Ditto		*pm*	*w*	Ba B^3F^1Aq	43		*a*				1	1	1·5†	
Carbonate	1	*pm*	*w*	Ba^2C O^4	50	4·331	*w*				2·75	9·5†		
	2	*pm*	*w*	Ba C O	24·5									
Bisulpho Ditto		*cr*	*y*	Ba C S^2O	32·5		*w*	*d*						
Ammonia Ditto		*ld*	—	Ba Am^2C O	33·5									
Cyanodide		*pr*	*w*	Ba C Z	24									
Sulpho Ditto	1	*pm*	*w*	Ba C S Z	28			*d*			1	1†		
	2	*ld*	*w*	Ba C Z S^2	32		*w*				24·3	49·1	16·6	
Ferro Ditto		*pm*	*y*	Ba C Z Fe	31						2	1	6†	
Cyanate		*nd*	*w*	Ba C Z O^2	32		*w*							
Fulminate	1	*pm*	*y*	Ba H C Z O	28·25		*w a*							
	2	*cr*	*w*	Ba H C Z^2O^2	35·75		*w a*							
Antimonite		*nd*	*w*	Ba Sb	28·5		*w*							
Antimoniate		*pr*	*w*	Ba Sb O^3	40·5		*w*							
Tellurate		*pr*	*w*	Ba Te O^2	41·5									
Sulpho Ditto		*pm*	*y*	Ba Te S O	41·5		*w*							
Tantalate		*pr*	*w*	Ba Ta O^2	40·5						23·75	9·5†		
Silicate		*pr*	*w*	Ba Si O	23·5									
Potash Ditto		*pr*	*w*	Ba K Si	33·5						14	21		
Fluo Ditto		*cr*	*w*	Ba Si^2F^3	35		*w*							

Uraniate		*pr*	*r*	Ba U O	56·5						28	9·5†	
Manganate	1	*ld*	*vi*	Ba Mn O^2	32·5								
	2	*pr*	*gn*	Ba Mn^2O	35·5								
Oxalate	1	*pr*	*w*	Ba C O^2	28·5						4·5	9·5	3·375†
	2	*pr*	*w*	Ba C^2O	27·5						9	9·5	3·375†
Croconate		*pr*	*y*	Ba C^5O^4	48·5								
Acetate		*nd*	*w*	Ba H C O^3	32·75	1·828	*w*				6·25	9·5	3·375†
Lactate		*gm*	*y*	Ba H C^3O^4	42·75								
Formate		*pm*	*bn*	Ba H C^2O^3	35·75						4·625	9·5†	
Mellate		*nd*	*w*	Ba H C^4O^3	41·75								
Tartrate	1	*cr*	*w*	Ba $H^2C^4O^3$	50						8·25	9·5†	
	2	*pm*	*w*	$Ba^2H^2C^4O^5$	67·5						16·5	9·5	2·25†
Pyro Ditto		*cr*	*w*	Ba $H^3C^6O^5$	56·25								
Potash Ditto		*pr*	*y*	Ba K $H^2C^6O^5$	60								
Soda Ditto		*pr*	*w*	Ba N $H^2C^6O^5$	56		*w*						
Vinate	1	*pr*	*w*	Ba H C^2O^4	39·75								
	2	*cr*	*w*	Ba^2H C^2O^4	57·25								
Sulpho Ditto		*pm*	*tr*	Ba H C^2S O^4	43·75		*w a*						
Citrate	1	*pr*	*w*	Ba $H^6C^4O^6$	55						1	1	
	2	*pr*	*w*	Ba $H^3C^2O^3$	36·25								
	3	*pr*	*w*	$Ba^2H^3C^2O^3$	53·75								
Pyro Ditto		*pr*	*w*	Ba $H^{10}C^4O^9$	68·5		*w*				7·43	9·5†	
Malate	1	*gm*	*w*	Ba H C^4O^4	45·75								
	2	*cr*	*w*	Ba^2H C^4O^4	63·25								
	3	*fk*	*w*	Ba $H^2C^3O^3$	39								
Pyro Ditto		*sc*	*w*	Ba H C O	56·5						6	9·75	
Fungate		*ld*	*w*	Ba H C O									
Mucate		*pr*	*w*	Ba $H^5C^6O^8$	68·75								
Pyro Ditto		*cr*	*w*	$Ba^2H^5C^6O^8$	86·25		*w*						
Succinate		*cr*	*w*	Ba $H^2C^4O^3$	42								
Benzoate		*cr*	*w*	Ba $H^5C^{14}O^3$	72·75		*w*						
Gallate		*fk*	*w*	Ba $H^7C^3O^4$	44·25								
Kinate		*cr*	*w*	Ba $H^4C^5O^4$	49·5								
Meconate		*pr*	*w*	Ba $H^9C^9O^4$	62·75								
Boletate		*pl*	*w*	Ba H C O			*w*						
Camphorate		*pl*	*w*	Ba H^3C^2O	28						?	9·5	3·9375†
Suberate		*pr*	*w*	Ba H^4C O^2	29·5		*w*						
Stearate		*pr*	*w*	Ba $H^{15}C^{14}O$	66·25								
Margarate		*pr*	*w*	Ba $H^{13}C^7O$	45·75		*w*						
Phocenate		*pr*	*w*	Ba H C O			*w*					9·5	

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Butyrate		*pr*	*w*	Ba $H^{11}C^{5}O^{3}$	56·25		*w a*							
Oleate	1	*pr*	*w*	Ba $H^{3}C^{14}O$	61·25		*a*							
	2	*pr*	*w*	$Ba^{2}H^{3}C^{14}O$										
Caproate		*pl*	*w*	Ba $H^{6}C^{4}O$	35			*ef*						
Caprate		*sd*	*w*	Ba $H^{10}C^{6}O$	42			*d*						
Cholesterate		*pr*	*r*	Ba H C O			*s*							
Pinate		*m*	*y*	Ba $H^{12}C^{11}O^{2}$	61									
Silvate		*pr*	*w*	Ba H C O			*w a*							
Carbazotate		*pm*	*w*	Ba $Z^{2}C^{5}O^{5}$	59·5									
Indigotate		*pr*	*y*	Ba $Z^{2}C^{15}O^{10}$	109·5									
Urate		*pr*	*w*	Ba Z $H^{2}C$ O	28·5						1	2·5		
Pyrurate		*pr*	*w*	$Ba^{2}H^{2}C$ O	42·5		*w*							
Aspartate		*cr*	*w*	Ba H C O										
Allentoate		*nd*	*w*	Ba $Z^{4}H^{8}C^{5}O^{4}$	64·5		*w*							
Sulpho naphthalate		*pr*	*w*	Ba $H^{6}C^{9}S$ O^{4}	66		*w a*							
Sinapate		*nd*	*w*	Ba Z $H^{9}C^{3}O^{4}$	48·25		*w*							
LITHIUM		*m*	*w*	L	1·5									
Oxide	1	*pr*	*w*	$L^{2}O$	7									
	2	*pr*	*w*	L O	5·5									
Hydrate		*pr*	*w*	L H O	5·75									
Sulpho Ditto		*pr*	*y*	L H S O	9·75		*a*	*d*						
Sulphite		*pr*	*y*	L S	5·5									
Sulphate	1	*cr*	*w*	L S O^{2}	13·5		*w*				5	1·75	1·125†	
	2	*tb*	*w*	L $S^{2}O$	13·5		*w*				68·4	31·6		
Ammonia Ditto		*tb*	*w*	L Am S O^{2}	18		*w*							
Soda Ditto		*cr*	*w*	L N S O^{2}	19·5		*w*							
Nitrate		*pm*	*w*	L Z O^{3}	17		*w*	*d*						
Chloride		*cr*	*w*	L C L	10·5		*w*	*d*						
Chloro hydrargyrate	1	*nd*	*w*	L Cl Mr	35·5		*w*	*d*						
	2	*pm*	*w*	L $Cl^{2}Mr$	44·5		*w*	*d*						

Fluoride	1	*pr*		L F	6		*w*					
	2	*pm*		L^2F	7·5		*w*					
Phosphite		*pr*	*w*	L P	5·5							
Phosphate	1	*pr*	*w*	L P O^3	17·5							
	2	*cr*	*w*	L P^2O	13·5							
Selenite		*pr*	*w*	L Se	11·5							
Arsenite		*pr*	*w*	L As	11							
Sulpho Ditto		*pr*	*r*	L As S^4	27							
Hypo Ditto Ditto		*pr*	*r*	L As S^5	31							
Arseniate	1	*pr*	*w*	L As O^3	23							
	2	*pr*	*w*	L As^2O^3	33·5							
	3	*pr*	*w*	L As O	15							
Sulpho Ditto	1	*cr*	*y*	L As S^2O^3	31							
	2	*m*	*y*	L As S O	19							
	3	*pl*	*y*	L As S O^3	27							
Chromate		*pm*	*y*	L Cr O^2	16·5		*w*					
Molybdate		*m*	*w*	L Mo	13·5		*w*					
Sulpho Ditto	1	*m*	*r*	L Mo S O^4	33·5		*w*					
	2	*pr*	*y*	L Mo S^2O^4	37·5		*w*					
Tungstate		*pm*	*w*	L W O^2	17·5		*w*					
Fluo silicate		*pm*	*w*	L Si^2F^3	19		*w*					
Oxalate	1	*cr*	*w*	L C O	8·5		*w*					
	2	*cr*	*w*	L C O^2	12·5		*w*					
Acetate		*cr*	*w*	L H C O^3	16·75		*w*	*d*				
Tartrate	1	*m*	*w*	L $H^2C^4O^5$	34		*w*	*d*				
	2	*cr*	*w*	L $^2H^2C^4O^5$	35·5		*w*					
Potash Ditto		*pm*	*w*	L K $H^2C^4O^5$	44		*w*					
Soda Ditto		*pm*	*w*	L N $H^2C^4O^5$	40		*w*					
Mucate		*pr*	*w*	L $H^5C^6O^8$	52·75			*ef*				
Malate		*cr*	*w*	L H C^4O^3	25·75							
Benzoate		*m*	*w*	L $H^5C^{14}O^3$	56·75		*w*	*d*				
Gallate		*m*	*bk*	L $H^7C^3O^4$	24·25		*w*					
Sulpho tellurate		*sd*	*y*	L Te S	13·5		*w a*	*d*				
Borate	1	*cr*	*w*	L B O^3	14·5			*d*				
	2	*cr*	*w*	L B^2O^3	15·5		*w*	*d*				
Fluo Ditto		*cr*	*w*	L B^2F^2	19		*w a*					
Carbonate	1	*pr*	*w*	L^2C O^3	21		*w*			2·75	1·75†	
	2	*pr*	*w*	L C O^2	15·5		*w*			54·46	45·54	
Bisulpho Ditto		*pr*	*y*	L C S^2O^2	24·5		*w a*	*d*				
Saclactate		*cr*	*w*	L H C^2O^4	29·75		*w*	*ef*				

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SODIUM		*sd*	*w*	N	6	0·97223								Soda
Oxide	1	*cr*	*gy*	N^2O	16									
	2	*cr*	*gy*	N O	10									
Hydrate		*pr*	*w*	N H O	10·25						4	1·125†		
Sulpho Ditto		*cr*	*y*	N H S	10·25			*d*			3	1·5		
Sulphite	1	*pl*	*w*	N^2S	16	1·466	*w*	*ef*			4	4	9†	
	2	*pm*	*y*	N^2S^3	24	2·95	*w*	*ef*			24·5	24·5	51	
	3	*pr*	*y*	$N\ S^2$	14						8	4	10·125†	
Sulphate	1	*pm*	*w*	$N^2S\ O^3$	28	2·246	*w*				5	4	11·25†	
	2	*pm*	*w*	$N^2S\ O$	20	2·645	*w*				5	4†		
	3	*pr*	*w*	N^2S^2O	24						9	9†		
	4	*cr*	*w*	$N\ S^2O^3$	26	2·26					7·5	4†		
	5	*cr*	*w*	$N\ S^2O$	18	1·800	*w*				10	4	4·5†	
	6	*pl*	*w*	N S O	14		*w*				9	4	2·25†	
Ammonia Ditto		*cr*	*w*	N Am S O	18·5						9	7·125	0·75†	
Carbo Ditto		*cr*	*w*	N C S O	17			*d*						
Nitrite		*pr*	*w*	N S Z	9·5									
Nitrate		*pm*	*w*	$N\ S\ O^3$	21·5	2·0694					6·75	4†		
Chloride		*cr*	*w*	N Cl	15	1·986	*w*				4·5	3†		
Chloro aurate	1	*pm*	*or*	$N\ Cl^2Au^2$	31·5		*w a*				2	1	6†	
	2	*pm*	*or*	$N\ Cl^2Au$	40·5		*w a*				2	1	8†	
Ditto Iridiate	1	*pm*	*bk*	$N\ Cl^2Ir$	56		*w a*							
	2	*tb*	*bk*	$N\ Cl^3Ir$	73		*w a*				1	1	9†	
Ditto Rhodiate		*pr*	*w*	N Cl R	21·5		*w a*				1	1	6	
Ditto Platinate		*pm*	*or*	N Cl Pt	27 25		*a*							
Ditto Palladiate		*pr*	*r*	N Cl Pd	21·5		*w a*							
Ditto hydrargyrate		*nd*	*w*	$N\ Cl^2Mr$	49		*w a*				2	4	1	
Ditto Stannate		*nd*	*w*	N Cl H	29·5		*w a*							
Chloride		*pl*	*w*	$N\ Cl\ O^3$	27		*w*				9·5	4		
Bromide		*cr*	*w*	N Bm	26		*w*				1	1		
Bromate		*pr*	*w*	$N\ Bm\ O^3$	38		*w*							
Iodide		*pm*	*w*	N I	38		*w*				1	1		
Iodo hydrargyrate		*pm*	*y*	N I Mr	63		*w*	*d*						
Iodate	1	*cr*	*w*	$N\ I\ O^3$	50		*w*	*d*			15·625	4		

Iodate	2	*pm*	*w*	N I^2O^3	82						20·75	4†	
Fluoride	1	*cb*	*w*	N F	10·5		*w*						
	2	*pm*	*w*	N F^2	15		*w*				2	1	2†
Phosphite	1	*cr*	*w*	N P	10		*w*						
	2	*pr*	*w*	N P^2	14			*d*					
Phosphate	1	*pm*	*w*	N P^2O^3	30	1·519					4·5	4	14·625†
	2	*pm*	*w*	N P^2O^3	26		*w*				9	4	9
	3	*m*	*w*	N P O	14						4·5	4	9†
	4	*pr*	*w*	N P^2O	18						9	4	4·5†
Pyro Ditto		*cr*	*w*	N P O^5	30						4·5	4	11·25†
Potash Ditto		*pr*	*w*	N K P O	24						10·5	8·5	19·125
Ammonia Ditto		*pm*	*w*	N Am^2P O	23	1·5					34·49	14·87	41·64
Carbo Ditto		*pr*	*w*	N C P O	17						6·75	25·5	45·0†
Selenite	1	*gr*	*w*	N Se	16								
	2	*cr*	*w*	N Se^2	26								
	3	*cr*	*w*	N^2Se^3	42								
Seleniate		*cr*	*w*	N Se O^3	28								
Arsenite		*sd*	*w*	N As	15·5								
Sulpho Ditto		*pr*	*br*	N As S^4	31·5		*w*						
Hypo Ditto Ditto		*pr*	*r*	N As S^5	35·5		*w*						
Arseniate	1	*pm*	*w*	N As O^3	27·5	1·76	*w*				7·25	4	14·0625†
	2	*pm*	*w*	N^2As O^3	33·5		*w*				7·25	4	8†
	3	*pr*	*w*	N As^2O	29						14·5	4	4·5†
Sulpho Ditto	1	*pr*	*y*	N As S^2O	23·5			*d*					
	2	*pl*	*br*	N As S O	27·5			*d*					
Potash Ditto		*pm*	*w*	N K S O	33·5		*w*				13·25	11·25	19·125
Ammonia Ditto		*pm*	*y*	N Am S O	49·5		*w*				9·375	11·25	11·25
Chromate	1	*pm*	*y*	N Cr O	21		*w*				6·5	4	13·5
	2	*pm*	*y*	N Cr O	24						13	4	22·25†
Potash Ditto		*cr*	*y*	N K Cr O	27		*w*				12·5	10·5	
Molybdate	1	*cr*	*w*	N Mo O^2	26		*w*						
	2	*cr*	*y*	N Mo^2O	34								
Sulpho Ditto		*pm*	*gn*	N Mo S O^4	38		*w*						
Hyper Ditto Ditto		*pr*	*y*	N Mo S O^5	42		*w*						
Tungstate	1	*pl*	*or*	N W O^2	22		*w*				18·75	4	6·75
	2	*cr*	*w*	N W O	18		*w*						
	3	*cr*	*w*	N W^3O^5	50		*w*						
Sulpho Ditto		*cr*	*r*	N W S O	22		*w a*	*d*					
Borate	1	*pm*	*w*	N B^5 O^3	23	1·351	*w*				6	4	9†
	2	*cr*	*w*	N B^2O^3	20	1·693	*w*	*ef*			2·75	8	9†

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Borate	3	*cr*	*w*	N B O	11		*w a*				6	4	4·5†	
Fluo Ditto		*pm*	*w*	N B^2F^3	23·5		*w a*							
Carbonate	1	*pr*	*w*	N^2C O^3	27	2·262					2·75	4	1·125†	
	2	*pr*	*w*	N H C O^3	21·25	1·623					2·75	4	11·25†	
	3	*pr*	*w*	$N^4H^2C^3O^9$	69·5	1·417	*w*				5·5	4	1·125†	
	4	*pr*	*w*	N C O	13	2·262	*w*				40	39·7	20·3	
	5	*cr*	*w*	N C^2O^3	24	1·51	*w*				2·75	4	9†	
	6	*cr*	*w*	$N^2C^2O^3$	30	1·980					4·125	4	2 25†	
Bisulpho Ditto		*cr*	*y*	N C S O	21		*a*							
Cyanodide		*pr*	*w*	N C Z	12·5		*a*							
Sulpho Ditto		*pm*	*w*	N C S Z	16·5		*al*	*d*						
Ferro Ditto		*pm*	*y*	N C Fe Z	19·5	1·458	*w a*	*ef*			2	1	12	
Fulminate		*cr*	*w*	N H C Z O	16·75		*a*				89	11		
Cyanate		*cr*	*w*	N H C Z O^3	24·75		*a*							
Antimonite		*cr*	*w*	N Sb	17		*w*							
Antimoniate		*cr*	*w*	N Sb O^5	29		*w*							
Tellurate		*cr*	*w*	N Te O^2	22		*w*							
Sulpho Ditto		*m*	*y*	N Te S O	26		*w*	*d*						
Tantalate		*sl*	*w*	N Ta O	25						19	4	11·25†	
Fluo Ditto		*pr*	*w*	N Ta^2F^5	49·5		*w*							
Ditto Titaniate		*m*	*w*	N Ti^2F^5	25·5		*w*							
Silicate		*gr*	*w*	N Si O	12		*w*	*d*						
Fluo Ditto		*pr*	*w*	N Si^2F^3	23·5		*w*							
Titanio Ditto		*pr*	*w*	N Si Ti O^2	19									
Manganate		*cr*	*w*	N Mm O^2	28									
Oxalate	1	*gn*	*w*	N C O^2	17		*w*				4·5	4†		
	2	*pm*	*w*	N C^2O^3	24	1·980	*w*				9	4	3·375	
Potash Ditto		*cr*	*w*	N K C O	23		*w*	*ef*						
Acetate		*pm*	*w*	N H C O^3	21·25	2·10	*w*							
Sulpho Ditto		*cr*	*w*	N H C S O	17·25		*w*				7	1		
Lactate		*cr*	*w*	N H C^3O^4	31·25		*w a*	*d*						
Formate		*pm*	*w*	N H C^2O^3	24·25						6·625	4	2·25†	
Mellate		*tb*	*w*	N H C^4O^3	30·25		*w*							

Tartrate	1	*nd*	*w*	N $H^2C^4O^5$	38·5	1·744	*w*				8·25	4	2·25†
	2	*cr*	*w*	$N^2H^4C^4O^5$	44·5		*w*						
	3	*cr*	*w*	N $H^3C^6O^5$	44·75		*w*				16·5	4	3·375†
Potash Ditto		*pm*	*w*	N K $H^2C^4O^5$	48·5		*w*	*ef*			54	46	
Boro Ditto		*cr*	*w*	N H $B^2C^4O^5$	39·5								
Vinate		*pm*	*w*	N H C^2O^4	28·25		*w*						
Sulpho Ditto		*tb*	*w*	N H C^3S O^4	32·25			*ef*					
Citrate		*tb*	*w*	N $H^6C^4O^6$	43·5		*w*	*ef*			60·7	39·3	
Malate	1	*m*	*w*	N H C^4O^4	34·5		*w*	*d*					
	2	*cr*	*w*	N^2H C^4O^4	40·25		*w*						
Fungate		*ld*	*w*	N H C O			*w*						
Mucate		*cr*	*w*	N $H^5C^6O^8$	57·25		*w*				13	4	5·625†
Pyro Ditto		*cr*	*w*	$N^2H^5C^6O^8$	63·25		*w*						
Succinate		*pm*	—	N $H^2C^4O^3$	30·5		*w*	*ef*			6·25	4	6·75†
Benzoate		*cr*	—	N $H^5C^{14}O^3$	61·25		*a*	*ef*					
Gallate		*m*	*bk*	N $H^7C^3O^4$	32·75								
Kinate		*cr*	*w*	N $H^4C^5O^4$	38								
Meconate	1	*cr*	*w*	N $H^9C^9O^4$	51·25		*w*	*ef*			32	40	28
	2	*gn*	*w*	$N^2H^9C^9O^4$	57·25		*w a*						
Camphorate		*cr*	*w*	N H^3C^2O	16·75		*w a*	*ef*					
Suberate		*nd*	*w*	N H^4C O^2	18		*w a*	*d*					
Stearate	1	*cr*	*w*	N $H^{15}C^{14}O$	55·75		*a*				1	1	
	2	*ld*	*w*	$N^2H^{15}C^{14}O$	61·75		*a*						
Margarate	1	*pl*	*w*	N $H^{13}C^7O$	34·25		*a*						
	2	*ld*	*w*	$N^2H^{13}C^7O$	40·25		*a*						
Ricinate		*sd*	*w*	N $H^{13}C^{14}O^3$	63·25		*w a*						
Oleate	1	*pr*	*w*	$N^2H^3C^{14}O$	58·75		*w a*						
	2	*pr*	*w*	N $H^5C^{14}O$	52·75		*w a*						
Phocenate		*cr*	*w*	N $H^{14}C^{11}O^5$	50·5			*d*					
Butyrate		*pr*	*y*	N $H^{11}C^8O^3$	44·75			*d*					
Caproate		*m*	*w*	N H^6C^4O	25·5								
Cholesterate		*pr*	*y*	N H^7C^6O	29·75		*a*						
Pinate		*gm*	*w*	N $H^{12}C^{11}O^2$	50		*al*						
Silvate		*m*	*bn*	N H C O			*w al*						
Carbazotate		*nd*	*y*	N Z^2H^5C O^4	48								
Urate		*pr*	*w*	N H^2C O	13·5		*al*						
Pyrurate		*pr*	*w*	N^2H^2C O	19·5		*w*						
Aspartate		*pr*	*w*	N H C O									
Sulpho naphthalate		*cr*	*y*	N H^6C^9S O^4	54·5								
Sinapate		*gn*	*w*	N Z $H^9C^3O^4$	36·75								

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POTASSIUM		*sd*	*w*	K	10	0·86507			136·5			6	1·125†	
Oxide	1	*pr*	*gy*	K^2O	24							6	4·5†	
	2	*pr*	*y*	K^2O^3	32									
	3	*cr*	*y*	K^5O^3	62									
Hydrate		*cr*	*w*	K H	10·25						20		0·125	
Sulpho Ditto		*fl*	*y*	K H S^2	18·25									
Sulphite	1	*pr*	*r*	K^2S	24		*w*				2	6†		
	2	*ld*	*r*	K H S^2	18·25		*w*				4	6†		
	3	*pl*	*w*	K S^2	18	1·586	*w*				6	6†		
	4	*pm*	*br*	K S^3	22		*w*				4	6†		
	5	*ld*	*br*	K S^4	26		*w*				8	6†		
	6	*pr*	*br*	K S^5	30		*w*				10	6†		
	7	*pr*	*ld*	K^2S^9	56		*w*							
	8	*pr*	*y*	K^5S^9	86		*w*							
Arsenio Ditto	1	*pr*	*w*	$K^3As^2S^5$	69		*w*							
	2	*pr*	*w*	$K^3As^2S^6$	73		*w*							
	3	*pr*	*w*	$K^3As^2S^8$	81		*w*							
	4	*pr*	*w*	K As S^2	27·5		*w*							
	5	*pr*	*w*	$K^2As^2S^5$	59		*w*							
	6	*pr*	*w*	$K^2As^2S^7$	67		*w*							
	7	*pr*	*w*	K As^2S^3	41		*w*							
	8	*pr*	*w*	K As^2S^4	45									
	9	*pr*	*w*	K As^2S^6	53									
Sulphate	1	*pm*	*c*	K S O^2	22	2·66	*w*				5	6†		
	2	*pm*	*pr*	K S^2O	22	2·67	*w*				5	6†		
	3	*pm*	*bn*	$K^2S^2O^5$	40						7·5	6	0·5625†	
	4	*cr*	*y*	K H S^2O^4	34·25						10	6	2·25†	
Hypo Ditto		*pr*	*w*	K^3S^2	38						9	6†		
Carbo Ditto		*cr*	*w*	K H C S O	21·25						60	36	4	
Ammonia Ditto		*pl*	*w*	K Am^2H C O	26·25	2·64	*w*				11	7·125	4·5	
Nitrite		*pr*	*w*	K Z	13·5						4·75	6†		
Nitrate		*pm*	*w*	K Z O^3	25·5	2·073	*w*				6·75	6†		
Chloride		*pm*	*w*	K Cl	19	1·98	*w*				4·5	6†		

Chloro osmiate	1	*pm*	*bn*	K Os^2Cl^5	62		*w a*					
	2	*pr*	*r*	K Os Cl	31·5		*w a*					
Ditto aurate	1	*pm*	*y*	K Au Cl^2	44·5					2	1	3†
	2	*pm*	*or*	K Au Cl	35·5					2	1	8†
Ditto iridiate	1	*cr*	*r*	K Ir Cl	31·5		*w a*					
	2	*cr*	*r*	K Ir Cl^2	40·25							
	3	*pm*	*r*	K Ir Cl^3	49·25							
Ditto rhodiate		*m*	*r*	K R Cl	25·5		*w a*			1	1	4†
Ditto platinate	1	*pm*	*r*	K Pt Cl	61·5		*w a*			1	1†	
	2	*pr*	*y*	K Pt Cl	31·25		*w a*			1	1†	
Ditto palladiate		*pr*	*r*	K Pd Cl	25·5					1	1†	
Ditto hydrargyrate	1	*pm*	*w*	K Mr Cl	44		*w a*			1	4	4†
	2	*nd*	*w*	K Mr Cl^2	53		*w a*			1	2	2†
	3	*pm*	*gy*	K Mr Cl^3	62		*w a*			1	1	1†
Ditto stannate		*pm*	*y*	K St Cl	33·5		*w*			1	1†	
Chlorate		*pl*	*w*	K Cl O^3	31	1·989	*w*			9·5	6†	
Bromide		*cr*	*w*	K Bm	30					10	6†	
Bromo hydrargyrate		*cr*	*y*	K Mr Bm	55		*w*			2	1†	
Bromate		*cr*	*y*	K Bm O^3	42					15	6†	
Iodide	1	*gn*	*w*	K I	42		*w a*			20·5	6†	
	2	*cr*	*w*	K^2I	52		*w a*			20·75	6†	
	3	*cr*	*w*	K I^2	74		*w a*			15·625	6†	
Iodo hydrargyrate		*nd*	*w*	K I Mr	67			*d*		15·625	6†	
Iodate		*cr*	*w*	K I O^3	54		*w a*			20·75	6†	
Fluoride	1	*m*	*y*	K F	14·5		*w*			1·25	6†	
	2	*cb*	*w*	K H F^2	19·25		*w*			2	1	2†
Phosphite	1	*m*	*br*	K^2P	24		*w*	*d*				
	2	*pr*	*ch*	K P	14		*a*	*d*				
Phosphate	1	*pr*	*w*	K^2P O^5	36		*w*			4·5	9†	
	2	*pm*	—	K P^2O	22		*w*			9	6	2·25†
	3	*m*	*w*	K P O	18	2·85	*w*			4·5	6	1·125†
Carbo Ditto		*pr*	*w*	K P C O	21		*w*					
Selenite	1	*pr*	*gn*	K Se	20		*w*					
	2	*pr*	*y*	K^2Se	30		*w*					
	3	*pl*	*r*	K Sl Se O^2	28·25		*w*					
Seleniate		*pr*	*gr*	K Se O^2	28		*w*			8	6†	
Arsenite		*m*	*br*	K As^2O^2	37		*w*					
Sulpho Ditto		*pr*	*w*	K As S O^4	39·5		*w*					
Hypo Ditto Ditto		*pr*	*br*	K As S O^5	43·5		*w*					

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Arseniate	1	*pm*	*w*	$K^3As^2O^4$	65	2·64	*w*				64	26	10	
	2	*m*	*w*	$K^4As^4O^7$	106		*w*							
	3	*pr*	*w*	$K\ As^2O^3$	41	2·638	*w*				14·5	6	1·6875†	
	4	*ld*	*w*	$K\ H\ As^2O^3$	41·25	1·1134								
Sulpho Ditto	1	*m*	*y*	$K\ As\ S\ O^3$	35·5									
	2	*pr*	*y*	$K\ As\ S^2O^3$	39·5		*a*							
Soda Ditto Ditto		*pm*	*y*	$K^2N^2As^4S^2O^9$	106		*a*							
Chromate	1	*pm*	*y*	$K^2Cr\ O^3$	39	2·6115	*w*				6·5	6†		
	2	*pr*	*w*	$K\ Cr\ O$	25		*w*				9·75	6†		
	3	*pm*	*or*	$K\ Cr^2O^3$	36	1·9801	*w*				13	6†		
Sulpho Ditto		*pr*	*y*	$K\ C\ S$	25		*a*				66	12·5		
Vanadite		*pr*	*w*	$K\ V\ O$	31									
Vanadiate	1	*pr*	*w*	$K\ V\ O^2$	35									
	2	*pr*	*w*	$K\ H\ V^2O^4$	60·25									
Molybdate	1	*pl*	*w*	$K\ Mo\ O^2$	26		*w*	*d*						
	2	*cr*	*w*	$K\ Mo^2O$	38		*w*	*d*						
Sulpho Ditto	1	*pr*	*r*	$K\ Mo\ S^4$	38		*w*							
	2	*sd*	*gn*	$K^2Mo\ S^4$	42		*w*							
Hyper Ditto Ditto		*m*	*r*	$K\ Mo\ S^5$	42		*w*							
Tungstate	1	*pr*	*w*	$K\ W\ O$	22		*w*	*d*						
	2	*pr*	*w*	$K\ W^3O^2$	42		*w*							
Sulpho Ditto	1	*cr*	*y*	$K\ W\ S\ O$	26		*w a*							
	2	*cr*	*y*	$K\ W^2S^3O$	38		*w a*							
	3	*cr*	*y*	$K\ W\ S^2O$	30		*w a*							
Nitro Ditto		*pr*	*w*	$K\ W\ Z\ O$	25·5		*w*							
Borate		*m*	*w*	$K\ B\ O^3$	23		*w*				2·75	6†		
Fluo Ditto		*pl*	*w*	$K\ W^3F^2$	43		*wa ac*							
Carburet		*m*	*bk*	$K\ C$	13									
Carbonate	1	*m*	*w*	$K^2C\ O^3$	35	2·34	*w*	*d*			2·75	6	2·25†	
	2	*pm*	*w*	$K\ H\ C^2O^3$	28·25	2·085	*w*				4·125	6	6·75†	
	3	*pl*	*w*	$K\ H\ C^2O^3$	28·25	2·012	*w*				5·5	6	1·125†	
Sulpho Ditto	1	*pr*	*w*	$K\ C\ S\ O$	21									
	2	*cr*	*r*	$K\ C\ S^2O$	25		*a*	*d*	260°					
Cyanodide		*pr*	*w*	$K\ C\ Z$	16·5						1	1		

Sulpho Ditto	1	*cr*	*y*	K C Z S	20·5					1	1	
	2	*m*	*r*	K C Z S^2	24·5		*a*	*d*				
Telluro Ditto		*cr*	*y*	K Te C Z	24·5							
Hydrargyro Ditto		*cr*	*w*	K Mr C Z	41·5							
Argento Ditto		*cr*	*y*	K Ag C Z	44							
Cupreo Ditto		*cr*	*y*	K Cu C Z	24·5							
Cobalt Ditto		*cr*	*r*	K Co C Z	23·5							
Nickel Ditto		*cr*	*y*	K Ni C Z	23·5							
Ferro Ditto	1	*pl*	*y*	$K^2C^3Z^3Fe$	46·5	1·83	*w*			1	2	3
	2	*cr*	*r*	$K^3C^6Z^6Fe^2$	83							
Zinc Ditto		*cr*	*y*	K C Z Zi	24·5							
Mangano Ditto		*cr*	*r*	K C Z Mu	23·5							
Fulminate		*pm*	*y*	K H C Z O	22·75					85	15	
Cyanate		*pl*	*w*	K H C Z O^3	28·75							
Antimonit	1	*pr*	*gy*	$K^2Sb^6O^5$	106					79·2	20·8	
	2	*cr*	*y*	$K^2Sb^{12}O^9$	188							
Antimoniate	1	*pr*	*bk*	K Sb^3O^3	55					76·6	23·4	
	2	*cr*	*bn*	K Sb^6O^7	104		*w*					
Telluret		*pr*	*w*	K Te	18							
Tellurate	1	*pr*	*w*	K Te O	22		*w*	*d*				
	2	*sd*	*bn*	K Te^2O^2	34·25		*w*	*d*				
Sulpho Ditto		*sd*	*bn*	K Te S^2	26		*w*	*d*				
Tantalate		*sl*	*w*	K Ta O	29		*w*					
Fluo Ditto		*sl*	*w*	K Ta^2F^3	53·5					1	1·5	
Titaniate		*pr*	*w*	K Ti O	17							
Fluo Ditto		*sl*	*w*	K Ti^2F^3	29·5		*w*			1	1·5	
Silicate	1	*gl*	*w*	K Si O	16		*w*			2	6	
	2	*gl*	*w*	K Si^3O^2	24							
	3	*sd*	*w*	K Si^4O^3	40							
Fluo Ditto		*pr*	*w*	K Si^2F^3	27·5		*w*			1	1	
Titanio Ditto		*pr*	*w*	K Si Ti^2	18							
Uraniate		*pr*	*y*	K U O^2	53					56	6	3·375†
Manganate		*pr*	*w*	K Mu O	25							
Oxalate	1	*pm*	*w*	K C O^2	21	2·034	*w*			4·5	6	1·125†
	2	*pm*	*w*	K C^2O^3	28	2·444	*w*			9	6	2·25†
	3	*pm*	*w*	K C O	17		*w*			18	6	7·875†
Ammonia Ditto		*nd*	*w*	K Am^2C O	26							
Acetate	1	*pm*	*w*	K H C O^3	25·25		*w*	*d*		6·25	6	2·25†
	2	*pl*	*w*	K H C^2O^3	28·25		*w*			12·5	6	6·75†
Lactate		*m*	*w*	K H C^3O^4	35·25		*w*					

Name of the Element, and its Combinations.		Form.	Colour.	Symbols of the Components, and their Quantities.	Atomic Weight.	Specific Gravity Water=1.	Solubility.	Atmospheric Action.	Fusing Temperature.	Colour of Precipitate by Test.	Theoretic Composition of Salts.			Trivial Name.
Formate		*pr*	*w*	K H C^2O^3	28·25		*w*				4·625	6†		
Mellate	1	*pm*	*vi*	K H C^4O^3	34·25		*w*							
	2	*cr*	*w*	K^2H C^4O^3	44·25		*w*							
Tartrate	1	*pm*	*w*	K $H^2C^4O^5$	42·5	1·556	*w*				8·25	6	2·25†	
	2	*pm*	*w*	$K^2H^2C^4O^5$	52·5	1·95	*w*				16·5	6	2·25†	
	3	*pl*	*w*	K $H^3C^6O^5$	48·75									
Ammonia Ditto		*pm*	*w*	K Am $H^2C^4O^5$	47									
Boro Ditto Ditto		*pr*	*w*	K H^2B Am C^4O^5	48									
Boro soda Ditto		*pr*	*w*	K H^2B N C^4O^5	49·5						10	22·5	13·5	
Vinate	1	*pr*	*w*	K H C^2O^4	32·25									
	2	*pr*	*w*	K^2H C^2O^4	42·25									
Sulpho Ditto		*pr*	*y*	K H C^2S O^4	36·25									
Citrate	1	*m*	*w*	K $H^6C^4O^6$	47·5		*w*				55·5	44·5		
	2	*pr*	*w*	K $H^5C^2O^3$	28·75									
Pyro Ditto		*nd*	*w*	K $H^{10}C^4O^9$	60·5		*w*							
Malate	1	*ld*	*w*	K H C^4O^4	38·25		*w a*							
	2	*cr*	*w*	K^2H C^4O^4	48·25									
	3	*cr*	*w*	K $H^2C^3O^3$	34·5									
Fungate		*ld*	*w*	K H C O			*w*							
Mucate	1	*gn*	*w*	K $H^5C^6O^8$	61·25		*w*							
	2	*pr*	*w*	$K^2H^5C^6O^8$	71·25		*w a*	*d*						
Succinate		*pm*	*w*	K $H^2C^4O^3$	34·5		*w*	*d*						
Benzoate	1	*nd*	*y*	K $H^5C^{14}O^3$	65·25		*w*	*d*			14·5	6	3·375†	
	2	*pl*	*y*	$K^2H^5C^{14}O^3$	75·25		*w*							
Croconate		*cr*	*y*	K H C^5O^4	41·25						7·73	6	2·25†	
Gallate		*m*	*bk*	K $H^7C^3O^4$	36·75									
Meconate		*pm*	*w*	K $H^9C^9O^4$	55·25		*w*							
Boletate		*m*	*w*	K H C O			*w*							
Camphorate		*cr*	*w*	K H^3C^2O	20·75		*w a*							
Suberate		*pm*	*w*	K H^4C O^2	22		*w*							
Stearate	1	*sl*	*w*	K $H^{15}C^{14}O$	59·75									
	2	*pr*	*w*	$K^2H^{15}C^{14}O$	69·75									
Margarate	1	*pr*	*w*	K $H^{15}C^7O$	38·25									
	2	*pr*	*w*	$K^2H^{15}C^7O$	48·25									

Ricinate		*sd*	*w*	K H C O		*w a*						
Oleate	1	*m*	*y*	K $H^{3}C^{14}O$	56·75							
	2	*m*	*y*	$K^{2}H^{3}C^{14}O$	66·75	*a*						
Phocenate		*pr*	*w*	K H C O								
Butyrate		*pr*	*w*	K $H^{11}C^{8}O^{3}$	47	*w*	*d*					
Caproate		*pr*	*w*	K $H^{6}C^{4}O$	27·5							
Hircate		*pr*	*w*	K H C O			*d*					
Crotonate		*pr*	*w*	K H C O								
Ambreate	1	*cr*	*w*	K H C O								
	2	*pr*	*w*	K H C O								
Cholesterate		*m*	*y*	K H C O			*d*					
Silvate	1	*ld*	*w*	K H C O								
	2	*pr*	*w*	K H C O								
Pinate		*cr*	*w*	K $H^{12}C^{11}O^{2}$	54							
Carbazotate		*cr*	*w*	K H $C^{5}O^{5}$	52					31	6†	
Indigotate		*pr*	*w*	K $Z^{2}C^{15}O^{10}$	102					35	6†	
Urate	1	*pr*	*w*	K Z $H^{2}C$ O	21							
	2	*cr*	*w*	K $Z^{2}H^{2}C$ O	31							
Aspartate		*pr*	*w*	K H C O								
Nitro saccharate	1	*nd*	*w*	K H C Z O								
	2	*nd*	*w*	K H C Z O								
Allentoate		*nd*	*w*	K $H^{8}C^{5}Z^{4}O^{4}$	57	*w a*						
Sulpho naphthalate		*pr*	*w*	K $H^{6}C^{9}S$ O^{4}	58·5	*w*						

OBSERVATIONS.

Ammoniacal gas liquefies by a pressure equal to almost 7 atmospheres; water solicits 780 volumes, the liquid is colourless, most pungent, destroys vitality, is strongly alkaline, combines and solidifies with muriatic acid gas, and alkalies and alkaline earths solicit it from substances where it is present. The strong liquid ammonia has a specific gravity 9·36, and boils at 130°; when salts of ammonia, alone or with caustic alkalies, or carbonated ditto, are heated in a glass tube, ammonia evolves, and is recognised by its peculiar odour; or when very diffuse, by white vapour, caused by the presence of a glass cane moistened with muriatic acid. Ammonia is indifferent to tartaric acid; but to chloride of platinum supplies a precipitate *yellow, crystalline.* Most of its salts are appropriated by water, and form crystals; and some of them without decomposition are by heat rendered volatile.

Thorium.—When sulphate of potash is present in solution with *Thorium*, double salts result, which are indifferent to a cold saturated solution of sulphate of potash; but when this is in excess, and the temperature is raised to 100° F., *Thorina* is precipitated; yet it is so extremely rare as to occur very seldom in chemical analysis. Treated with caustic potash and caustic ammonia, its solutions supply a white gelatinous precipitate; *white*, flocculent, with phosphate of soda, indifferent to phosphoric acid; *white* also with ferrocyanate of potash, hydrosulphuret of ammonia, oxalic acid, and carbonated alkalies (excess of which appropriates the precipitate); Thorium is only subject to the concentrated sulphuric acid. Thorina, the oxide, is indifferent to excess of oxalic acid. Sulphate of Thorina is partially appropriated by concentrated acids, and cold (not hot) water. The blow-pipe flame reduces thorina and borax to a colourless bead, which resists opacity by the flame.

Zirconium.—Concentrated sulphuric acid appropriates more of this element than any other acid. The neutral solution of zirconium, when boiled with a saturated solution of sulphate of potash, supplies a disalt of zirconia, *white;* also by succinated alkalies, by phosphate of soda, by ferrocyanate of potash, hydrosulphuret of ammonia, oxalic acid (the precipitate appropriated by great excess of muriatic acid), by potash, soda and ammonia;

also by carbonated alkalies (imperfectly precipitated, and sluggishly appropriated by excess of test). The blow-pipe analysis only with difficulty detects the salts.

ALUMINUM.—The hydrate is precipitated, *white*, by caustic potash or soda (and excess again appropriates it), caustic ammonia, carbonated alkalies, and hydrosulphuret of ammonia. When needed in quantitative analysis, it is most carefully washed, and all water is evaporated by long incandescense. The hydrate also is by infusion of galls very sluggishly precipitated from solutions in the weaker acids; and, while indifferent to the succinate and binoxalate of potash, is readily precipitated by the bicarbonate of soda; it is soluble in caustic potash, from which as a *white* precipitate it is thrown down by muriate of ammonia and boiling, and likewise by hydrosulphuret of ammonia from neutral solutions, while sulphuretted hydrogen evolves. Alum, in octahedral crystals, is the result of combining sulphates of alumine and potash. The blow-pipe analysis detects *alumine*, pure or in compounds, by roasting on a charcoal support a small portion of the substance, next adding solution of nitrate of cobalt, and again heating the assay; the colour appears *dirty* violet by reflected or candle light, but when cold, is a *beautiful blue*.

YTTRIUM forms a double salt with sulphate of potash, by concentrated cold solutions again appropriated, but very sluggishly, afterwards precipitated, *white*, also by oxalic acid (indifferent to excess), and to succinated alkalies, potash, soda, phosphate of soda, ammonia, hydrosulphuret of ammonia, and carbonated alkalies (soluble in excess), and *greyish white* by ferrocyanate of potash, and *dirty white* by nutgall infusion: also *white* carbonate, by boiling the solution of yttria and carbonate of ammonia. When the solutions in carbonated alkalies are precipitated, many of the salts are amethystine in colour, and sweetish in savour. The Blow-pipe analysis requires like treatment with alumine for yttria and glucina, and a *dark grey* or *black* tint results with the latter, but the former is not easily recognised.

GLUCINUM.—The precipitated hydrate is *yellow*, by treating solutions of the weaker acids with infusion of nutgalls. It does not form a double salt with potash and sulphuric acid. It is precipitated, *white*, by potash and carbonated alkalies (soluble in excess of these); soda, phosphate of soda, hydrosulphuret of ammonia, also by the succinate, but not the binoxalate of potash;

and boiling the solution of carbonate of ammonia precipitates carbonate of glucina; the salts have a pleasant savour.

Magnesium in solutions is indifferent to oxalates, and sluggishly to sulphuric acid; but supplies a *white* precipitate to caustic potash, caustic ammonia (when the muriate is absent), and to carbonated alkalies; the first usually disappears on the exhibition of muriate of ammonia, as likewise always does each of the others, but re-appears when raised to 212° F.; concentrated solution supplies a *white* precipitate to carbonated ammonia, and sluggishly to carbonated soda, but not to the bicarbonate; the precipitated carbonate is readily appropriated by carbonic acid; the precipitate by phosphate of ammonia is usually, that by binoxalate of potash always, *white, crystalline;* also *white* when plus of alkali is present, to hydrosulphuret of ammonia; water appropriates the sulphate, and alcohol the nitrate and muriate, which two are deliquescent. The assay heated on a charcoal support, then moistened with solution of nitrate of cobalt, and again highly heated, becomes dull *red* (or garnet).

Calcium.—Solution of lime is indifferent to bicarbonate of soda, and to hydrofluosilicic acid; but neutral solution supplies a *white* precipitate to oxalates, *crystalline* (as gypsum), in concentrated, to sulphuric acid and sulphates; in dilute, to binoxalate of potash, indifferent to water, also to oxalic acid; but appropriated by plus of nitric or muriatic acid; the precipitated carbonate is appropriated by plus of carbonic acid. Concentrated solutions supply needles of nitrate or deliquescent chloride, which like the other soluble salts of this base (and those of *strontia*), when present in inflamed alcohol, cause the flame to be red (or *carmine*); and when the assay with either present is heated at the point of the blow-pipe inner flame, a beautiful faint red (or strong carmine) tint appears until it is fused.

Strontium, in solution, is indifferent to hydrofluosilicic acid, but supplies a *white* precipitate to sulphuric acid and sulphates, partially solicited by acids, but not by water, which solicits those supplied to oxalates; neutral and dilute solutions are sluggishly troubled by oxalic acid and binoxalate of potash; the nitrate is indifferent to alcohol, which solicits the muriate. The assay of the chloride by the blow-pipe inner flame has a carmine tint while fusing, evanescent when fused (as in that of calcium).

Barium, in solution, on the exhibition of sulphuric acid or

sulphates soluble in water, supplies a precipitate, *white*, indifferent to water, nitric, or muriatic acid, likewise to binoxalate of potash, phosphates, oxalates, and carbonates, quickly when ammonia is present, and the last class solicited by plus of carbonic acid; *pale lemon yellow* to chromates; a *yellow*, *crystalline*, to ferrocyanate of potash; and sluggishly, a crystalline to hydrofluosilicic acid. The nitrate and the muriate are indifferent to alcohol. The presence of barytes is with difficulty detected by the blow-pipe.

Lithium supplies salts, which are readily solicited by water (except the carbonate and phosphate sluggishly); to carbonate of ammonia they give a *white* precipitate, very minute to tartaric acid; and *yellow*, *crystalline*, to chloride of platinum, the chloride is very deliquescent, and is readily solicited by alcohol. Lithia renders the blow-pipe outer flame *carmine red*, not affected by potash, but yellow when soda is present, and it solicits and renders yellow the part of the platinum foil on which it is fused.

Sodium decomposes water without inflammation, forming soda, which in solutions is indifferent to every re-agent that is a base, but supplies a slight copious opalescent precipitate to hydrofluosilicic acid. The soda salts readily are solicited by water; the sulphate has prism crystals, grooved, bevelled hexagonal; the nitrate has rhomboids deliquescent; the chloride has pyramids quadrangular, indifferent to atmospheric action, and solicited by alcohol; the carbonate has rhomboidal laminæ, or decahedrons of two quadrangular pyramids; like the sulphate, efflorescent. The yellow flame, when the minutest portion is present, renders soda useful as a very delicate test.

Potassium potently solicits oxygen, and when appropriating that of water, the heat evolved inflames the hydrogen; concentrated solutions often sluggishly supply to chloride of platinum a *yellow crystalline* precipitate, very bright ditto to alcoholic solution of carbazotic acid, and to tartaric acid, *white*, *crystalline* (bitartrate of potash). Many of its salts are indifferent to atmospheric action. The sulphate has crystals, hexahedral prisms with hexagonal pyramids; the nitrate has six-sided flattened prisms, with dihedral summits; the chloride has cubes or rectangular parallel opipedons. The assay fused on platinum wire, and then again heated at the point of the inner flame, renders the outer purple or violet; and the tint is *blue* when borax and nickel are used.

Name of the Element, and its Combinations.		Form.	Colour.	Symbols of the Components, and their Quantities.	Atom. Wt. and Numbers, Equivalent Hyd. = 25.	Specific Gravity Water = 1·000.	Fusibility, Fahrenheit.	Fusibility, Wedgwood.	Solubility.	Atmospheric Action.	Theoretic Composition. Acid.	Base.	Water.	Trivial Name.
SELENIUM		*sd*	*bl*	Se	10	1·431	690*b*							
Oxide		*g*	—	Se O	14									
Acid (Selenious)	1	*g*	—	Se O^2	18				*w a*	*d*				
(Selenic)	2	*g*	—	Se O^3	22	2·6								
Hydro Ditto		*g*	—	Se H O^3	22·25									
Sulphuret		*ld*	*or*	Se^2S^3	32									
Chloride	1	*cr*	*y*	Se Cl	19									
	2	*cr*	*w*	Se Cl^2	28									
Bromide		*sd*	*br*	Se Bm^2	50									
Phosphoret		*ld*	*br*	Se P	14									
ARSENIC		*sd*	*bk*	As	9·5	5·7653	356*s*							
Oxide	1	*pr*	*bk*	As^2O	23									
	2	*pr*	*w*	As^3O	32·5									
Hydrate		*ld*	—	As H O	13·75									
Acid (Arsenious)		*pr*	*w*	$As^{11}O^3$	116·5	3·7								
(Arsenic)		*pr*	*w*	$As^{11}O^5$	124·5									
Sulphuret	1	*pr*	*r*	As^2S	23									
	2	*cr*	*r*	As S	13·5	3·3384								
	3	*pr*	*y*	As S^2	17·5									
	4	*pr*	*r*	As S^3	21·5									
	5	*pl*	*y*	As^2S^3	31	3·4522								
	6	*pr*	*y*	As^2S^5	39									
	7	*cr*	*y*	As S^9	45·5									
	8	*pr*	*r*	As S										
	9	*pr*	*y*	As S										
	10	*pr*	*r*	As S										
	11	*pl*	*y*	As S										
	12	*pl*	*r*	As S										
Chloride		*pm*	*w*	As^2Cl^3	46	6·4888								
Bromide		*pr*	*w*	As^2Bm^3	79									
Iodide		*pr*	*w*	As^2I^3	115									

Fluoride		*ld*	—	As^2F^3	32·5							
Phosphoret		*sd*	*bk*	As P	13·5							
Seleniuret		*sd*	*br*	As Se	19·5							
Ferrocyanodide		*pr*	*w*	As Fe C Z	23							
CHROMIUM		*sd*	*w*	Cr	7	5·9						
Oxide	1	*pr*	*gn*	Cr O	41							
	2	*pr*	*bn*	Cr^4O^3	40							
Acid	1	*pr*	*r*	Cr^2O^5	34							
	2	*pr*	*or*	Cr S O^3	23							
Sulphite		*pr*	*gy*	Cr S	11							
Sulphate		*m*	*gn*	$Cr^2S\ O^3$	30				5	5	3·375†	
Nitrate		*pr*	*br*	Cr Z O^3	22·5				6·75	5	3·375†	
Chloride	1	*sl*	*r*	Cr^2Cl^5	41			*w*				
	2	*cr*	*gn*	Cr Cl^2	25			*w*				
Chlorochromic Acid		*pr*	—	Cr Cl O^3	28	1·9134						
Bromide	1	*ld*	*gn*	Cr^2Bm^3	74			*w a*				
	2	*ld*	*r*	Cr Bm	27			*w a*				
Fluoride	1	*pr*	*gn*	Cr^2F^3	27·5			*w a*				
	2	*pr*	*r*	Cr F	11·5			*w a*				
Phosphoret		*pr*	*br*	Cr P	11							
Phosphate		*pr*	*gn*	Cr P^2O^3	23				9	5	6·75†	
Arsenite		*pr*	*gn*	Cr As	16·5							
Sulpho Ditto		*pr*	*gn*	Cr As S	20·5							
Arseniate	1	*pr*	*y*	Cr As O^3	28·5				7·25	5		
	2	*pr*	*gn*	Cr As^2O^3	38				14·5	5	6·75†	
Sulpho Ditto		*pr*	*y*	Cr As S O	24·5							
Chromate	1	*pr*	*bn*	Cr Cr^2O^3	33							
	2	*pr*	*bn*	$Cr^7Cr^2O^9$	99							
Molybdate		*pr*	*gn*	Cr Mo O^2	27							
Sulpho Ditto		*pr*	*bn*	Cr Mo S O	27			*w*				
Ditto Tungstate		*pr*	*bn*	Cr W S O^2	27			*w*				
Carbonate	1	*pr*	*bl*	$Cr^2C\ O^3$	29							
	2	*m*	*bl*	Cr C^2O	17			*w*	2·75	10	4·5†	
	3	*pr*	*bn*	Cr C^3O	20				2·75	15	1·125	
	4	*pr*	*br*	Cr C^5O	26				2·75	25	23·725	
Bisulpho Ditto		*pr*	*gn*	Cr C S^2O	22							
Potash Ditto		*ld*	*gn*	K Cr C O^2	28							

Name of the Element, and its Combinations.		Form.	Colour.	Symbols of the Components, and their Quantities.	Atom. Wt. and Numbers, Equivalent Hyd. = 25.	Specific Gravity Water = 1·000.	Fusibility, Fahrenheit.	Fusibility, Wedgwood.	Solubility.	Atmospheric Action.	Theoretic Composition.			Trivial Name.
											Acid.	Base.	Water.	
Sulphocyanodide		*pr*	*gn*	Cr C Z S	17·5				*w*					
Ferro ditto.....		*fk*	*gn*	Cr Fe C Z	20·5				*w*					
Fulminate		*cr*	*gn*	Cr H C Z O	17·75				*w*					
Sulpho Tellurate.....		*sd*	*bk*	Cr Te S	19									
Fluo silicate.....		*m*	*w*	Cr Si^2F^3	24·5				*w*	*d*				
Oxalate	1	*m*	*bk*	Cr C O^2	18						4·5	5	3·375	
	2	*cr*	*bk*	Cr C^2O^3	25									
Acetate		*pr*	*gn*	Cr H C O^3	22·25									
Tartrate	1	*pr*	*bl*	Cr $H^2C^4O^5$	39·5						8·25	5	2·25	
	2	*pr*	*bl*	$Cr^2H^2C^4O^5$	46·5									
Potash Ditto		*pr*	*bk*	K Cr $H^2C^4O^5$	49·5						14·25	13·25	2·25	
Citrate		*cr*	*gn*	Cr $H^6C^4O^6$	42·5									
Succinate.....		*cr*	*vi*	Cr $H^2C^4O^3$	31·5									
Oleate		*cr*	*vi*	Cr $H^3C^{14}O$	53·75									
VANADIUM.....			*w*	V	17									
Oxide.....	1			V^2O	38									
	2			V O	21									
Acid.....	1			V^2O^3	46									
	2			V^4O^5	88									
Sulphite.....	1			V S^2	25									
	2			V S^3	29									
Sulphate.....	1			V S^2O^4	41									
	2			V S^3O^6	53									
Nitrate.....				V Z O^3	32·5									
Chloride.....	1			V Cl	26									
	2			V^2Cl^3	61									
Bromide.....				V^2Bm^3	37									
Iodide	1			V I	49									
	2			V^2I^3	130									
Fluoride	1			V F	21·5									
	2			V^2F^3	47·5									

Phosphite				V P	21							
Phosphate				V P O^3	33							
Seleniate				V Se O^3	39							
Arsenite				V As	26·5							
Sulpho Ditto				V As S	30·5							
Arseniate				V As O^3	38·5							
Sulpho Ditto				V As S O^3	42·5							
Chromate				V Cr O^2	32							
Molybdate				V Mo O^2	37							
Tungstate				V W O^2	33							
Borate				V B O^3	30							
Carbonate				V^2C O^3	32							
Cyanodide				V C Z	23·5							
Fulminate				V H C Z O	29·75							
Tellurate				V Te O^2	33							
Tantalate				V Ta O^2	40							
MOLYBDENUM		*gr*	*y*	Mo	12	8·620						
Oxide	1	*pr*	*bk*	Mo^2O	28							
	2	*pr*	*br*	Mo O	16							
	3	*pm*	*bk*	Mo^3O^4	52							
Potash tartrate Ditto		*pr*	*bn*	K Mo $H^2C^4O^5$	54·5							
Acid	1	*ld*	*w*	Mo O^3	24	3·40						
	2	*pr*	*w*	Mo^3O^5	56							
Potash tartrate Ditto		*gm*	*w*	K Mo $H^2C^4O^6$	58·5					42	58	
Sulphite	1	*pr*	*bl*	Mo S^2	20	4·591						
	2	*pr*	*bk*	Mo S^3	24							
	3	*pr*	*r*	Mo S^4	28							
Sulphate	1	*cr*	*y*	Mo^2S O^2	36			*w*	*d*			
	2	*m*	*y*	Mo S^2O	24							
	3	*pr*	*y*	Mo S O^2	24							
Nitrate	1	*ld*	—	Mo Z O^3	39·5							
	2	*ld*	—	Mo Z^2O^3	31							
	3	*ld*	—	Mo Z O	19·5							
Chloride	1	*pr*	*r*	Mo Cl	21							
	2	*pr*	*r*	Mo Cl^2	30							
	3	*pr*	*r*	Mo Cl^3	39							
Bromide		*pr*	*w*	Mo^2Bm^3	84							

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											Acid.	Base.	Water.	
Iodide	1	*pr*	*bk*	Mo^2I^3	120									
	2	*cr*	*br*	Mo H I	44·25									
Fluoride		*pr*	*bl*	Mo^2F^3	37·5									
Phosphate	1	*m*	*y*	$Mo^2P\ O^3$	40				*w a*					
	2	*m*	*s*	$Mo\ P^2O^3$	32									
	3	*pr*	*gy*	$Mo\ P^2O$	24									
	4	*gm*	*r*	$Mo\ P\ O^3$	28									
Ammonia Ditto		*pr*	*bn*	Am Mo P O	24·5									
Arsenite		*sd*	*br*	Mo As	21·5									
Sulpho Ditto		*pr*	*bn*	Mo As S	25·5				*w*					
Arseniate	1	*fk*	*w*	$Mo\ As\ O^3$	33·5									
	2	*ld*	*bl*	$Mo^2As\ O^3$	45·5									
	3	*gm*	*pr*	$Mo\ As^2O$	35									
Sulpho Ditto		*pr*	*bn*	Mo As S O	29·5									
Chromate	1	*ld*	*y*	$Mo\ Cr\ O^2$	27									
	2	*gm*	*y*	$Mo^2Cr\ O^2$	39									
	3	*gm*	*br*	$Mo^2Cr^2O^3$	50									
	4	*m*	*br*	$Mo\ Cr^2O^2$	34									
	5	*pr*	*br*	$Mo\ Cr^2O$	30									
Molybdate		*pr*	*y*	Mo Mo O^2	32									
Tungstate		*pr*	*y*	Mo W O^2	28									
Ammonia Ditto		*pr*	*w*	Am Mo W O	28·5									
Borate	1	*cr*	*y*	$Mo\ B\ O^3$	25				*w*					
	2	*cr*	*y*	$Mo\ B^2O^3$	26				*w*					
	3	*gm*	*y*	$Mo^2B\ O^3$	37				*w*					
Carbonate		*pr*	*gn*	$Mo^2C\ O^3$	39									
Potash Ditto		*pr*	*y*	K Mo H C O^2	33·5					*d*				
Ammonia Ditto	1	*pr*	*w*	Am $Mo^2C^4O^5$	60·5									
	2	*pr*	*y*	$Am^2Mo^2C^4O^5$	65									
Soda Ditto	1	*pr*	*y*	N Mo C O	25					*d*				
	2	*pr*	*y*	N Mo^2C O	37					*d*				
Sulpho cyanodide		*pr*	*bn*	Mo C Z S	22·5									
Ferro Ditto	1	*pr*	*bn*	Mo C Z Fe	25·5									
	2	*pr*	*bn*	Mo^2C Z Fe	37·5									

Oxalate	1	*ld*	*gy*	Mo C O^2	23								
	2	*gm*	*w*	Mo C^2O^2	26				*a*				
	3	*cr*	*y*	Mo^2C O^2	35				*a*				
Potash Ditto	1	*pr*	*w*	K Mo C O^2	33								
	2	*pr*	*y*	K Mo^2C O^2	45								
Acetate	1	*pr*	*y*	Mo H C O^3	27·25				*w*				
	2	*ld*	—	Mo^2H C O^3	39·25								
	3	*gm*	*gy*	Mo H C O	19·25								
Tartrate	1	*ld*	*bl*	Mo $H^2C^4O^5$	44·5				*w*				
	2	*ld*	*bk*	$Mo^2H^2C^4O^5$	56·5				*w*				
	3	*pr*	*gy*	Mo $H^3C^6O^5$	50·75				*w*				
Potash Ditto		*pr*	*gy*	K Mo $H^3C^6O^5$	60·75				*w ac*				
Succinate	1	*ld*	*gy*	Mo $H^2C^4O^6$	36·5				*w*				
	2	*cr*	*y*	$Mo^2H^2C^4O^7$	48·5				*w*				
	3	*pr*	*y*	Mo $H^{12}C^{16}O^5$	79·5				*w*				
TUNGSTEN		*sd*	*w*	W	8	17·4							
Oxide	1	*pr*	*br*	W^2O	28								
	2	*pr*	*r*	W O	12								
Soda Ditto		*cr*	*or*	N W^2O	26					18·75	4	6·75†	
Acid		*ld*	*y*	W O^3	20	6·5							
Sulphite	1	*pr*	*bk*	W S^2	16								
	2	*pr*	*br*	W S^3	20								
Sulphate		*pr*	*w*	W S O^2	20				*w*				
Nitrate		*pr*	*y*	W Z O^3	23·5				*w*				
Chloride	1	*pr*	*r*	W^3Cl	33								
	2	*pr*	*y*	W Cl^2	26								
	3	*pr*	*r*	W Cl^3	55								
Bromide		*pr*	*y*	W^2Bm^3	76								
Iodide		*pr*	*r*	W^2I^3	112								
Phosphite		*pr*	*y*	W^2P^3	18								
Antimoniate		*sd*	*br*	W^3Sb^6	75								
ANTIMONY		*sd*	*w*	Sb	11	6·4366	810						
Oxide		*pr*	*gy*	Sb O	15								

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											Acid.	Base.	Water.	
Acid	1	*pr*	*w*	Sb^2O^3	34									
	2	*pr*	*y*	Sb^4O^7	72									
Potash tartrate Ditto		*cr*	*w*	$K\ Sb^1H^2C^4O^2$	114·5									
Sulphite	1	*pr*	*or*	Sb^2S	26									
	2	*pr*	*gy*	Sb S	15									
	3	*pr*	*y*	Sb S^2	19									
	4	*pr*	*or*	Sb S^3	23									
	5	*pr*	*y*	Sb^2S^3	34									
	6	*pr*	*br*	Sb^2S^5	42									
Iodo Ditto		*pr*	*br*	$Sb^2I^3S^2$	130									
Sulphate	1	*pr*	*w*	Sb S O^2	23						5	23·75		
	2	*pr*	*y*	Sb^6S^4O	86									
	3	*pr*	*or*	Sb^3S^4O	53									
Nitrate		*pr*	*w*	Sb Z O^3	26·5						6·75	38		
Chloride	1	*m*	*w*	Sb^2Cl^3	49									
	2	*cr*	*w*	Sb^2Cl^5	67									
	3	*cr*	*w*	Sb Cl^2	29									
Ammonia Ditto		*pr*	*y*	Am Sb Cl^2	33·5									
Bromide		*pr*	*or*	Sb^2Bm^3	82									
Iodide		*pr*	*or*	Sb^2I^3	118									
Fluoride		*cr*	*w*	Sb^2F^3	35·5									
Phosphite		*pr*	*w*	Sb P	15									
Phosphate		*pr*	*gn*	Sb P O^3	27									
Selenite		*m*	*br*	Sb Se	21									
Arsenite		*sd*	*w*	Sb As	20·5									
Sulpho Ditto		*pr*	*or*	Sb As S^2	28·5									
Arseniate		*pr*	*w*	Sb As O^3	32·5									
Sulpho Ditto		*pr*	*y*	Sb As S O	28·5									
Chromate		*pr*	*y*	Sb Cr O^2	26									
Molybdate		*pr*	*y*	Sb Mo O^2	31									
Fluo silicate		*pm*	*gn*	Sb Si^2F^3	27·5				*w*					
Oxalate		*gn*	*gn*	Sb C O^2	22				*w*					
Potash Ditto		*nd*	*w*	K Sb C O^2	32				*w*					
Acetate		*cr*	*w*	Sb H C O^3	26·25				*w*					

Tartrate	1	*gm*	*w*	Sb $H^2C^4O^5$	43·5				*w*				
	2	*pr*	*y*	$Sb^2H^2C^4O^5$	54·5				*w*				
Potash Ditto		*pm*	*y*	K Sb $H^2C^4O^5$	53·5					2	2	1	2
Baryto Ditto		*pr*	*w*	Ba Sb $H^6C^4O^5$	72					2	2	1	2
Argento Ditto		*pr*	*w*	Sb Ag $H^6C^4O^5$	82					23	27·25	2·25	
Calcareo Ditto		*pr*	*w*	Ca Sb $H^2C^4O^5$	48·5								
Croconate		*pr*	*y*	Sb C^5O^4	42								
Succinate		*pr*	*w*	Sb $H^2C^4O^5$	35·5								
Benzoate		*cr*	*w*	Sb $H^5C^{14}O^6$	78·25								
Gallate		*cr*	*w*	Sb $H^7C^5O^4$	53·5								
TELLURIUM		*sd*	*w*	Te	8	6·1379							
Oxide		*pr*	*w*	Te O	12								
Acid		*pr*	*w*	Te O^2	16								
Sulphuret	1	*pr*	*gy*	Te^2S	20								
	2	*pr*	*w*	Te S	12								
Sulphate		*pr*	*w*	Te S O^2	20								
Nitrate		*cr*	*w*	Te Z O^3	23·5								
Chloride	1	*ld*	*w*	Te Cl	17								
	2	*pr*	*w*	Te Cl^2	26								
Iodide		*pm*	*w*	Te^2I^3	112								
Phosphate		*pr*	*w*	Te P O^5	24								
Seleniuret		*pr*	*w*	Te Se	18								
Seleniate		*pr*	*w*	Te Se O^2	26								
Arseniate		*pr*	*w*	Te As O^3	29·5								
Chromate	1	*pr*	*y*	Te Cr O^2	23								
	2	*gm*	*y*										
Molybdate		*pr*	*w*	Te Mo O^2	28								
Tungstate		*pr*	*w*	Te W O^2	24				*w*				
Carbonate		*pr*	*bk*	Te^2C O^3	31								
Benzoate		*pr*	*w*	Te $H^5C^{14}O^6$	75·25				*w*				
TANTALUM		*sd*	*w*	Ta	15								
Oxide		*pr*	*y*	Ta^3O	49								
Acid		*pr*	*or*	Ta^2O	34	6·5							
Hydrate		*ld*	—	Ta^2H O	34·25					1	11		

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											Acid.	Base.	Water.	
Hydro Fluo Ditto.....		*m*	*or*	Ta H^2F^5	43·75									
Sulphuret		*pr*	*gy*	Ta S	19						3	1		
Sulphate.....		*pr*	*or*	Ta S O^2	27									
Chloride	1	*gs*	—	Ta Cl	24						3	1		
	2	*pr*	*w*	Ta^2Cl	39									
	3	*pr*	*w*	Ta^2Cl^3	69									
Bromide		*pr*	*y*	Ta^2Bm^3	90									
Iodide.....		*pr*	*vi*	Ta^2I^3	126									
Fluoride.....		*pr*	*w*	Ta^2F^3	43·5									
Phosphate		*pr*	*y*	Ta P O^5	31									
Tungstate		*pr*	*or*	Ta W O^2	31									
Borate.....		*pr*	*w*	Ta B O^3	28									
Ferrocyanodide.....		*pr*	*y*	Ta Fe C Z	28·5									
TITANIUM		*pr*	*or*	Ti	3	5·3								
Oxide		*cr*	*bl*	Ti^2O	10	3·826								
Acid.....		*pr*	*br*	Ti O^2	11	4·249								
Hydrate.....		*ld*	—	K H O^2	11·25									
Sulphuret	1	*pr*	*gn*	Ti S	7									
	2	*pr*	*y*	Ti S^2	11				*w*					
Sulphate.....	1	*m*	*or*	Ti S O^2	15						7·78	76·83	15·39	
	2	*pm*	*y*	Ti S^2O	15						7·56	76·50	15·94	
Nitrate.....		*pm*	*w*	Ti Z O^3	18·5									
Chloride	1	*gm*	*y*	Ti Cl	12	6·896	275							
	2	*cr*	*or*	Ti Cl^2	21	6·8055								
Bromide.....		*pr*	*y*	Ti^2Bm^3	66									
Iodide.....		*pr*	*or*	Ti^2I^3	102									
Fluoride		*pr*	*y*	Ti F	7·5									
Potash Ditto.....		*pr*	*or*	K Ti^2F^3	29·5									
Phosphoret.....		*pr*	*w*	Ti P	7									
Phosphate.....		*pr*	*w*	Ti P O^5	19									
Arseniate		*pr*	*w*	Ti As O^3	24·5									

Carbonate		*pr*	*br*	$Ti^2C\ O^3$	21								
Potash Ditto		*pr*	*w*	$K\ Ti^2C\ O^3$	31								
Ammonia Ditto		*pr*	*y*	$Am^3Ti^2C\ O^3$	34·5								
Soda Ditto		*pr*	*w*	$N\ Ti^2C\ O^3$	27								
Ferrocyanodide		*pr*	*bn*	Ti Fe C Z	16·5								
Axalate		*pr*	*y*	Ti C O^2	14						4·5	31·5	6·75†
Ocetate		*gm*	*w*	Ti H C O^3	18·25								
Tartrate		*pr*	*bk*	Ti $H^2C^4O^5$	35·5								
Gallate		*pr*	*bn*	Ti $H^7C^3O^4$	29·75								
SILICIUM		*pr*	*bn*	Si	2	1·837							
Oxide		*pr*	*bn*	Si^2O	8								
Hydrate (many ?)		*pr*	—	H Si O	?								
Acid		*pr*	*br*	Si O	6	2·65							
Sulphite		*m*	*w*	Si S	6						2	1†	
Chloride		*ld*	—	Si Cl	11	5·939							
Bromide		*pr*	*w*	Si^2Bm^3	64								
Iodide		*pr*	*w*	Si^2I^3	100								
Fluoride		*pr*	*br*	Si^2F^3	17·5	3·5735							
Carburet		*pr*	*bn*	Si C	5								
Carbonate		*cr*	*w*	$Si^2C\ O^3$	19								
Soda Ditto		*gn*	*w*	$N\ Si^2C\ O^3$	25								
Silicate		*pr*	*w*	Si Si	4								
Fluosilicate		*pr*	*bn*	$Si^2Si\ F^3$	19·5								
OSMIUM		*sd*	*w*	Os	12·5	10			*ac*				
Oxide	1	*pr*	*bk*	Os O	16·5								
	2	*pr*	*bl*	Os^2O^3	37								
	3	*pr*	*bl*	Os O^2	20·25								
	4	*pr*	*bk*	Os O^4	28·5								
	5	*pr*	*bk*	Os O^5	32·5								
	6	*pr*	*br*	Os^3O^4	53·5								
Sulphite	1	*pr*	*br*	Os^2S	29								
	2	*pr*	*br*	Os^3S^2	45·5								
	3	*pr*	*br*	Os^4S^3	62								
	4	*pr*	*br*	Os S	16·5								

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											Acid.	Base.	Water.	
Sulphite	5	*pr*	*br*	Os^4S^5	70									
	6	*pr*	*br*	Os^2S^3	37									
	7	*pr*	*br*	$Os\ S^2$	20·5									
	8	*pr*	*br*	$Os\ S^4$	28·5									
Chloride	1	*pr*	*gn*	$Os\ Cl$	21·5									
	2	*pr*	*gn*	$Os\ Cl^2$	30·5									
	3	*pr*	*r*	Os^2Cl^3	52									
	4	*pr*	*r*	Os^4Cl^3	77									
Potash Ditto		*pr*	*bn*	$K\ Os^2Cl^3$	62									
GOLD		*sd*	*y*	Au	16·5	19·3	2590	32						
Oxide	1	*pr*	*gn*	Au^2O	37									
	2	*pr*	*bn*	$Au\ O$	20·5									
	3	*pr*	*br*	Au^2O^3	45									
Sulphite	1	*pr*	*bk*	$Au\ S$	20·5									
	2	*pr*	*br*	Au^2S^3	45									
Sulphate		*pr*	*y*	$Au\ S\ O^2$	28·5									
Nitrate	1	*ld*	*br*	$Au\ Z\ O^3$	32									
	2	*ld*	*br*	$Au\ Z^2O^5$	43·5									
Soda Ditto		*pr*	*br*	$N\ Au\ Z^2O^3$	41·5									
Chloride	1	*nd*	*r*	Au^3Cl	58·5				*w*					
	2	*m*	*r*	$Au\ Cl$	25·5				*w*	*d*				
	3	*nd*	*br*	Au^2Cl^3	60				*w*					
Soda Ditto		*cr*	*y*	$N\ Au^2Cl^3$	66				*w*		69·3	16·6	14·1	
Bromide		*yr*	*r*	Au^2Bm^3	93									
Iodide		*pr*	*br*	Au^2I^3	129									
Iodate		*pr*	*y*	$Au\ I\ O^3$	60·5									
Phosphoret		*cr*	*w*	Au^4P	70									
Arsenite		*pr*	*or*	$Au\ As^2$	35·5									
Sulpho Ditto		*pr*	*br*	$Au\ As\ S^4$	42		320							
Hypo Ditto Ditto		*pr*	*gy*	$Au\ As\ S^5$	46		300							
Arseniate		*pr*	*y*	$Au\ As^2O^3$	47·5									

Sulpho Arseniate.....		*pr*	*bn*	Au As S^2O	38								
Chromate.....		*pr*	*or*	Au Cr O^2	31·5								
Molybdate.....		*pr*	*y*	Au Mo O^2	36·5				*w ac*				
Sulpho Ditto.....		*pr*	*bk*	Au Mo S O^4	44·5				*w*				
Hyper Ditto Ditto.....		*pr*	*bn*	Au Mo S^5O	48·5				*w*				
Sulpho Tungstate.....		*pr*	*bk*	Au W^3S O^2	52·5					*ef*			
Boride.....		*pr*	*bn*	Au B	17·5								
Bisulpho carbonate...		*pr*	*gy*	Au C S^2	27·5								
Cyanodide.....		*pr*	*y*	Au Z C	23				*am*				
Sulpho Ditto.....		*pr*	*y*	Au Z C S^2	31				*ac*				
Ferro Ditto.....		*pr*	*gn*	Au Z C Fe	30								
Cyanurate.....		*pr*	*or*	Au Z Cl C O^2	31·25				*am*				
Fulminate.....		*pr*	*bn*	Au Z H C O	27·25				*al*				
Antimonite.....		*pr*	*y*	$Au^2Sb^6O^5$	119								
Sulpho Tellurate.....		*fk*	*bk*	Au Te S^2	32·5								
Acetate.....		*pr*	*y*	Au H C O^3	31·75								
Pinate.....		*pr*	*y*	Au H^7C^7O	46·25								
Benzoate.....		*cr*	*or*	Au H^2C^5O	36				*w*				
IRIDIDIUM.....		*gn*	*w*	Ir	12·25	23·5		170					
Oxide.....	1	*pr*	*bk*	Ir^4O	53								
	2	*pr*	*bl*	Ir^8O^3	110								
	3	*pr*	*bl*	Ir^4O^3	61								
	4	*pr*	*bl*	Ir^2O^3	37								
	5	*gm*	*br*	Ir O^3	24·25								
Sulphite.....	1	*pr*	*br*	Ir^3S	40·75								
	2	*pr*	*br*	Ir^2S	29								
	3	*pr*	*br*	Ir S	16·25								
	4	*pr*	*br*	Ir^2S^3	37								
Sulphate.....		*pr*	*r*	Ir S O^2	24·25								
Nitrate ?.....													
Chloride.....	1	*pr*	*gn*	Ir Cl	21·25								
	2	*pr*	*br*	Ir^2Cl^3	51·5								
	3	*cr*	*bk*	Ir Cl^2	30·25								
	4	*pr*	*bk*	Ir Cl^3S	43·25								
Potash Ditto.....	1	*m*	*r*	K Ir^2Cl^2	52								
	2	*cr*	*r*	$K^2Ir^4Cl^5$	114								
	3	*cr*	*r*	K Ir^2Cl^3	61·5								

Name of the Element, and its Combinations.		Form.	Colour.	Symbols of the Components, and their Quantities.	Atom. Wt. and Numbers, Equivalent Hyd. = 25.	Specific Gravity Water = 1·000.	Fusibility, Fahrenheit.	Fusibility, Wedgwood.	Solubility.	Atmospheric Action.	Theoretic Composition.			Trivial Name.
											Acid.	Base.	Water.	
Potash Chloride.....	4	*cr*	*r*	K Ir^2Cl^4	70·5									
Ammonia Ditto.....		*cr*	*r*	Am Ir^2Cl^2	47·5									
Soda Ditto.....		*cr*	*r*	N Ir^2Cl^2	49									
Baryto Ditto.....		*cr*	*r*	Ba Ir^2Cl^2	60·5									
Carburet ?.....														
RHODIUM.....		*pr*	*w*	R	6·5	10·649		170						
Oxide.....	1	*gn*	*y*	R O	10·5									
	2	*pr*	*bk*	R O^2	14·5									
	3	*fk*	*y*	R^2O^3	25									
Sulphite.....		*pr*	*bn*	R^2S	17									
Sulphate.....		*m*	*w*	R S O^2	18·5				*w*	*d*				
Nitrate.....		*ld*	*r*	R Z O^3	22				*w*					
Soda Ditto.....		*cr*	*r*	N R Z^2O^3	31·5									
Chloride.....	1	*pr*	*y*	R Cl	15·5									
	2	*ld*	*r*	R Cl^2	24·5									
	3	*cr*	*r*	R^2Cl^3	40									
	4	*pr*	*r*	R Cl^4	42·5									
Soda Ditto.....		*pr*	*y*	N R Cl^2	30·5				*w*					
Arseniate.....		*pr*	*w*	R As^2O^5	37·5									
Acedate.....		*ld*	*y*	R $H^3C^4O^3$	31·25									
Soda Ditto.....		*pr*	*y*	N R $H^3C^4O^3$	37·25				*w*					
PLATINUM.....		*sd*	*w*	Pt	12·25	21·47		170						
Oxide.....	1	*pr*	*bk*	Pt^2O	28·5						78·32	10·84	10·84	
	2	*pr*	*gy*	Pt O	16·25									
	3	*pr*	*gy*	Pt^2O^3	37									
	4	*pr*	*br*	Pt^2O^4	41									
Potash Ditto.....		*pr*	*bn*	K Pt O	26·25									
Ammonia Ditto.....		*pr*	*gy*	Am Pt O	20·75									

Sulphite	1	*pr*	*bk*	Pt S	16·25	6·2							
	2	*pr*	*gy*	Pt^2S^3	37								
	3	*pr*	*gy*	$Pt\ S^2$	20·25	3·5							
Potash Ditto		*pr*	*bn*	K Pt S^2	30·25								
Sulphate	1	*ct*	*bk*	Pt S O^2	24·25				*a ac*	*d*	26·3	73·7	
	2	*ld*	*gn*	Pt S^2O^2	28·25								
Potash Ditto		*pr*	*bn*	K Pt S O^2	34·25						78·3	10·84	10·84
Ammonia Ditto		*pr*	*r*	Am Pt S O^2	28·75							70	30
Soda Ditto		*gr*	*y*	N Pt S O^2	30·25						7·1	84	8·9
Baryto Ditto		*pr*	*bn*	Ba Pt S O^2	37·75								
Alumine Ditto		*pr*	*bk*	Al Pt S O^2	26·5								
Nitrate	1	*pr*	*bk*	Pt Z O^3	27·75								
	2	*pr*	*br*	$Pt^2Z\ O^3$	40·5				*w*				
Potash Ditto		*pr*	*w*	K Pt Z O^3	37·75								
Ammonia Ditto		*pr*	*w*	Am Pt Z O^3	32·25								
Soda Ditto		*pr*	*w*	N Pt Z O^3	33·75								
Chloride	1	*cr*	*gn*	Pt^2Cl	33·5								
	2	*pr*	*gn*	Pt Cl	21·25								
	3	*pr*	*br*	Pt Cl^2	30·25								
Potash Ditto		*cr*	*y*	K Pt Cl^2	40·25						6·75	21	
Ammonia Ditto	1	*pr*	*r*	Am Pt Cl^2	34·75						6·5	8·	70
	2	*pr*	*y*	Am Pt^2Cl^3	56						14·7	42	15·5
Soda Ditto	1	*cr*	*y*	N Pt Cl^2	36·25								
	2	*pr*	*r*	N Pt^2Cl^3	57·5								
Bromide	1	*pr*	*y*	Pt Bm	32·25								
	2	*pr*	*y*	Pt Bm^2	52·25								
Iodide	1	*pr*	*y*	Pt I	44·25								
	2	*pr*	*y*	Pt I^2	76·25								
Iodate		*pr*	*y*	Pt I O^3	56·25								
Fluoride	1	*pr*	*y*	Pt F	16·75								
	2	*pr*	*y*	Pt F^2	20·25								
Phosphoret	1	*pr*	*w*	Pt P^2	20·25								
	2	*pr*	*gy*	Pt^3P^2	44·75								
	3	*pr*	*gy*	Pt^2P^5	45								
Selenite		*pr*	*gy*	Pt Se	22·25								
Arsenite		*pr*	*gy*	Pt As^2	31·25								
Sulpho Ditto		*pr*	*gy*	Pt As^2S^4	47·25								
Hypo Ditto Ditto		*pr*	*bk*	Pt As^2S^5	51·25								
Arseniate		*pr*	*br*	Pt As^2O^3	43·25								
Sulpho Ditto		*pr*	*y*	Pt As S^2O	33·75								

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											Acid.	Base.	Water.	
Chromate		*pr*	*r*	Pt Cr O^2	27·25									
Molybdate		*sd*	*gy*	Pt Mo O^2	32·25									
Sulpho Ditto		*pr*	*bn*	Pt Mo S O^2	36·25				*w*					
Ditto Tungstate		*pr*	*bk*	Pt W S O^2	32·25				*w*					
Boride		*cr*	*gy*	Pt B	13·25									
Bisulpho Carbonate		*pr*	*bk*	Pt C S^2O^3	35·25									
Cyanodide		*pr*	*w*	Pt Z C^2	21·75				*w*					
Sulpho Ditto		*pr*	*w*	Pt Z C^2S^2	29·75				*al*					
Hydro Sulpho Ditto		*pr*	*y*	Pt Z H C^2S^2	30									
Cyanurate		*pr*	*y*	Pt Z $H^2C^2O^4$	38·25									
Fulminate		*pr*	*bn*	Pt Z H C O	33									
Antimoniate		*pd*	*gy*	$Pt^2St^6O^5$	111									
Sulpho Tellurate		*fk*	*bk*	Pt Te S O	28·25									
Silicate		*pr*	*gy*	$Pt^{33}Si$	398									
Fluo Ditto		*pr*	*bn*	Pt F^3Si^2	31·75				*w*					
Oxalate		*cr*	*y*	Pt C^2O^3	30·25									
Acetate		*m*	*br*	Pt H C O^3	27·5									
Benzoate		*cr*	*y*	Pt H^2C^5O	31·75									
Camphorate		*pr*	*w*	Pt $H^9C^{19}O$	48·5									
PALLADIUM		*pr*	*w*	Pd	6·5	12		170						
Oxide	1	*pr*	*bl*	Pd^2O	17									
	2	*pr*	*bk*	Pd O	10·5									
Sulphite	1	*pr*	*w*	Pd^2S	17									
	2	*sd*	*w*	Pd S	10·5									
Sulphate	1	*pr*	*r*	Pd S O^2	18·5									
	2	*pr*	*br*	Pd S^2O	18·5									
Nitrate	1	*ld*	*r*	Pd Z O^5	22									
	2	*pr*	*r*	Pd^2Z O^3	28·5									
Chloride	1	*cr*	*r*	Pd^2Cl	20									
	2	*ld*	*r*	Pd Cl	15·5									
	3	*pr*	*br*	$PdCl^2$	24·5									

Potash Chloride.....	1	*cr*	*r*	K Pd^2Cl^3	50								
	2	*cr*	*r*	K Pd^2Cl^2	41								
Ammonia Ditto.....		*ld*	*y*	Am Pd Cl^2	29·5				*w*				
Soda Ditto.....		*m*	*r*	N Pd Cl^2	31·5				*w*				
Bromide.....		*pr*	*r*	Pd^2Bm^3	73								
Iodide.....		*pr*	*r*	Pd^2I^3	109								
Iodate.....		*pr*	*y*	$Pd^2I^3O^3$	131								
Phosphoret.....		*pr*	*w*	Pd P	10·5								
Selenite.....		*sd*	*gy*	Pd Se	16·5								
Arseniate		*m*	*y*	$Pd^3As^2O^4$	49·5								
Carburet.....		*sd*	*bk*	Pd C	9·5								
Cyanodide.....		*fk*	*y*	Pd Z C^2	16								
Sulpho Ditto.....		*pr*	*y*	Pd Z C S^2	21								
Fulminate.....		*pr*	*bn*	Pd Z H C O	17·25								
Oxalate.....		*pr*	*y*	Pd C^2O^3	21·5								
Citrate.....		*pr*	*y*	Pd $H^2C^4O^4$	35								
Benzoate.....		*pr*	*w*	Pd $H^5C^{14}O^3$	61·75								
MERCURY		*fd*	*w*	Mr	25	15·612	656						
Oxide	1	*fd*	*w*	Mr^2O	54	10·69							
	2	*fd*	*w*	Mr O	29								
	3	*fd*	*w*	Mr O^2	33	11·29			*w*				
Sulphite	1	*pr*	*r*	Mr S	29								
	2	*pr*	*bk*	Mr S^2	33								
Sulphate.....	1	*pr*	*w*	Mr^2S O^2	62				*w*				
	2	*pr*	*w*	Mr^2S O^3	66								
	3	*pr*	*y*	Mr S O^2	37	6·44			*w*		15·6	84·4	U
	4	*pr*	*y*	Mr S^2O	37				*w*		5	26	1·6875
	5	*pr*	*w*	Mr S O	37								
	6	*cr*	*w*	Mr S^2O^2	41				*w*		10	27	1·125U
Hyponitrite.....		*pr*	*y*	Mr Z O	32·5								
Nitrate.....	1	*cr*	*w*	Mr^2Z O^5	65·5				*w*		6·75	27	2·25†
	2	*pr*	*w*	$Mr^2Z^2O^3$	69				*w*		6·75	26	2·25†
	3	*pr*	*w*	Mr Z^2O^3	44						6·75	39	1·6825†
	4	*pm*	*w*	Mr Z O^3	40·5				*w*		6·75	54	
	5	*pr*	*w*	Mr Z^2O	36						6·75	52·10	
	6	*pm*	*w*	Mr Z^2O^6	58				*w*	*d*	13·5	13·5	
Ammonia Ditto.....	1	*pr*	*w*	Am Mr Z O^2	45								

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											Acid.	Base.	Water.	
Ammonia Nitrate.....	2	*pr*	*w*	$Am^2Mr\ Z\ O^3$	49·5						6·75	2·125	40·5†	
Chloride.....	1	*pm*	*w*	Mr^2Cl	59	7·176			*w*		4·5	25†		
	2	*pm*	*w*	Mr Cl	34	5·14			*w*		4·5	12·5†		
Ammonia Ditto.....	1	*pr*	*w*	$Am^2Mr\ Cl$	43				*w*					
	2	*pr*	*w*	Am Mr Cl	38·5				*w*					
Chlorate.....	1	*nd*	*w*	Mr Cl O^6	58									
	2	*gr*	*y*	Mr Cl O^7	62									
Bromide.....	1	*pm*	*w*	Mr^2Bm	70						10	25†		
	2	*pm*	*w*	Mr Bm	45						10	12·5†		
Ammonia Ditto.....	1	*pm*	*w*	$Am^2Mr\ Bm$	54									
	2	*pr*	*w*	Am Mr Bm	49·5									
Iodide.....	1	*m*	*g*	Mr^2I	82				*w*		15·75	25†		
	2	*pr*	*y*	Mr I	57				*w*		15·75	12·5†		
	3	*pr*	*gn*	Mr^2I^3	146				*w*					
Ammonia Ditto.		*pr*	*w*	Am Mr I	61·5									
Iodate.....		*pr*	*y*	$Mr^2I^3O^3$	158									
Fluoride.....	1	*cr*	*y*	Mr F	29·5				*w*					
	2	*pm*	*y*	Mr F^2	34				*w*					
Phosphite.		*pr*	*bk*	Mr P	29									
Phosphate	1	*pr*	*w*	Mr P O^2	37						4·5	13·5†		
	2	*pr*	*w*	Mr P^2O	37	4·98					28·5	71·5	U	
Selenite.....	1	*pl*	*w*	Mr Se^2	45				*w al*					
	2	*pr*	*y*	Mr Se	35									
Arsenite.....		*sd*	*gy*	Mr^2As	59·5									
Sulpho Ditto.....	1	*pr*	*gn*	Mr As S^4	50·5									
	2	*pl*	*y*	$Mr^2As\ S^4$	75·5									
Hypo Ditto Ditto.....		*pr*	*w*	Mr As S^5	54·5									
Arseniate.	1	*m*	*y*	Mr As^2O^3	56									
	2	*pr*	*y*	$Mr^2As^2O^3$	110						7·25	26†		
Sulpho Ditto.....	1	*pr*	*y*	Mr As S O^3	50·5									
	2	*pr*	*bn*	Mr As S^2O^5	54·5									
Chromate.	1	*pr*	*y*	Mr Cr O^2	40				*w*					
	2	*pr*	*r*	Mr Cr^2O	43				*w*		6·5	26†		
Molybdate.....		*pr*	*w*	Mr Mo O^2	45				*w*					

Sulpho Molybdate.....		*pr*	*bn*	Mr Mo S^4O	57					*w*					
Hyper Ditto Ditto.....		*pr*	*bn*	Mr Mo S^5O	61					*w*					
Tungstate.		*pr*	*w*	Mr W O^2	47					*w*					
Sulpho Ditto.....	1	*fk*	*y*	Mr W S^4O	53										
	2	*pr*	*bk*	Mr W S O	41										
Borate.....		*pr*	*y*	Mr B O^3	38	2·66									
Carbonate	1	*pr*	*br*	Mr^2C O^3	65							4·125	26†		
	2	*pr*	*w*	$Mr^2C^2O^3$	43							2·75	26†		
Bisulpho Ditto.....	1	*pr*	*bk*	Mr C S^2O^3	48					*w*					
	2	*pr*	*bk*	Mr^2C S^2O^3	73					*w*					
Cyanodide.....	1	*cr*	*w*	Mr C Z	31·5					*w a*		1	1†		
	2	*nd*	*w*	Mr C Z^2	35					*w a*		2	3†		
Ammonia Ditto.....		*pr*	*w*	Am Mr C Z	36										
Sulpho Ditto.....	1	*pr*	*w*	Mr C Z S	35·5										
	2	*pr*	*y*	Mr C Z S^2	39·5										
Ferro Ditto.....		*pr*	*w*	Mr C Z Fe	38·5										
Cyanate.....		*pr*	*w*	Mr H C Z O^2	39·75										
Fulminate	1	*pr*	*gy*	Mr H C Z O	35·29										
	2	*pr*	*w*	Mr H^2C Z O	35·5										
Antimoniate.....		*pr*	*or*	Mr Sb^2O^3	70										
Tellurate.....		*pr*	*w*	Mr Te O	37										
Sulpho Ditto.....	1	*pr*	*bn*	Mr Te S O	41										
	2	*pr*	*bn*	Mr Te S^2O	45										
Fluo silicate.....	1	*pr*	*bn*	Mr Si^2F^3	42·5										
	2	*pr*	*bn*	Mr Si F^2	36										
Oxalate	1	*pr*	*w*	Mr C O^2	36										
	2	*pm*	*y*	Mr C O	32							4·5	26†		
Potash Ditto.....		*pm*	*gy*	K Mr C O	42					*w*					
Acetate.....	1	*pl*	*w*	Mr $H^3C^4O^3$	49·75					*w*	*d*	6·25	27†		
	2	*m*	*y*	Mr $H^3C^4O^4$	53·75					*w*	*d*	6·25	13·5†		
Lactate.....	1	*m*	*w*	Mr $H^6C^5O^8$	76·25					*w*	*d*				
	2	*m*	*r*	$Mr^2H^6C^5O^8$	98·5					*w*	*d*				
Formate....		*pm*	*w*	Mr H^2C O^3	40·5					*w*					
Mellate.....	1	*pr*	*w*	Mr C^4O^3	49					*w*					
	2	*pr*	*w*	Mr C^4O^5	57					*w*					
Tartrate.....	1	*pr*	*w*	Mr $H^2C^4O^5$	57·5							9·25	26		U
	2	*pr*	*w*	$Mr^2H^2C^4O^5$	82·5							8·25	26†		
Pyro Ditto.....	1	*pr*	*bn*	Mr $H^6C^4O^4$	57·75										
	2	*pr*	*br*	$Mr^2H^3C^4O^4$	78·75					*w a*	*d*				

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Potash Ditto	1	*cr*	*w*	K Mr $H^2C^4O^5$	67·5									
	2	*pr*	*y*	K $Mr^2H^2C^4O^5$	92·5									
Vinate		*pr*	*bk*	Mr H C^2O^4	47·25									
Citrate	1	*m*	*w*	Mr $H^6C^4O^6$	62·5				*w*					
	2	*pr*	*w*	Mr $H^{12}C^4O^6$	87·5									
Malate	1	*pr*	*w*	Mr H C^4O^4	53·25				*w*					
	2	*gm*	*w*	Mr^2H C^4O^4	68·25				*w*					
Pyromucate		*pr*	*w*	Mr H C^2O^3	43·25									
Succinate	1	*m*	*w*	$Mr^2H^2C^4O^3$	74·5				*w*					
	2	*cr*	*w*	Mr $H^2C^4O^3$	49·5									
Benzoate	1	*pr*	*w*	Mr $H^5C^{14}O^3$	80·25				*a*					
	2	*nd*	*w*	Mr H^2C O	44·5									
Meconate		*pr*	*w*	Mr $H^9C^9O^6$	70·25									
Camphorate		*pr*	*gy*	Mr H^3C^2O	35·75				*w*					
Suberate		*pr*	*w*	Mr H^4C O^2	37									
Pinate	1	*pr*	*or*	Mr H^7C^3O	51·75									
	2	*fk*	*w*	$Mr^2H^7C^7O$	76·75									
Silvate	1	*pr*	*y*	Mr H C O										
	2	*fk*	*bn*	Mr H C O										
Carbazotate		*pm*	*y*	Mr $H^2C^5O^7$	68·25				*w*					
Pyrurate		*pr*	*bn*	Mr $H^2C^3O^2$	46									
Indigotate		*pr*	*w*	Mr H C^3O^2	42·25						100	73·4†		
Sulpho naphthalate	1	*pr*	*y*	Mr H^6C^9S O^4	75·5					*d*				
	2	*cr*	*w*	Mr $H^9C^9S^2O^4$	77·5					*d*				
Sinapate		*pr*	*w*	Mr $H^9C^3O^4$	56·25									
SILVER		*m*	*w*	Ag	27·5	10·474	1830							
Oxide	1	*pr*	*br*	Ag^2O^2	90·5									
	2	*pr*	*gy*	Ag O	31·5	7·143								
	3	*pr*	*bk*	Ag O^2	35·5									
Sulphite	1	*gr*	*bk*	Ag S	31·5	7·2			*w*					
	2	*gr*	*w*	Ag S O	35·5									

Potash Ditto		*sc*	*w*	K Ag S O^2	49·5				*w ac*				
Ammonia Ditto		*m*	*w*	Am Ag S O^2	44								
Hypo Ditto Ditto		*fk*	*gy*	Am^2Ag S^2O^2	60·5								
Soda Ditto		*pl*	*w*	N Ag S O^2	45·5								
Strontian Ditto		*pr*	*w*	Sr Ag S O^2	50·5				*w*				
Calcareo Ditto		*m*	*w*	Ca Ag S O^2	44·5				*w*		1	1	
Sulphate	1	*pm*	*w*	Ag S O^2	39·5								
	2	*pr*	*w*	Ag S^2O^2	43·5								
Hypo Ditto		*pr*	*gy*	Ag S^2O^3	47·5								
Ammonia Ditto	1	*pr*	*w*	Am Ag S O^2	44								
	2	*pr*	*w*	Am Ag S^2O^2	48								
Hyponitrite		*pr*	*y*	Ag Z O^2	39								
Nitrate		*pl*	*w*	Ag Z O^3	43	3·521			*w*		6·75	14·75†	
Ammonia Ditto		*cr*	*w*	Am^2Ag Z O	44				*w*		26·4	55	18
Chloride		*m*	*w*	Ag Cl	36·5	5·129	500		*w*		4·5	13·875	
Ammonia Ditto		*pr*	*w*	Am^2Ag^2Cl	86·5								
Chlorate		*pm*	*gn*	Ag Cl O^3	48·5				*w*				
Bromide		*pr*	*y*	Ag^2Bm^3	115								
Iodide		*pr*	*y*	Ag^2I^3	151								
Iodate		*pr*	*w*	$Ag^2I^3O^3$	163								
Fluoride		*m*	*w*	Ag^2F^3	68·5				*w*				
Phosphoret		*pr*	*w*	Ag P^2	39·5								
Phosphate	1	*pr*	*w*	Ag P O^2	43·5	7·321					17	83	
	2	*pr*	*y*	Ag P^2O^3	45	5·306					4·5	22·125†	
Pyro Ditto		*pr*	*w*	Ag H^2C^3P O	45						4·5	14·75†	
Selenite	1	*pr*	*bk*	Ag^2Se	65						7	14·75†	
	2	*pr*	*gy*	Ag Se	37·5								
Arsenite		*pr*	*gy*	Ag^2As	64								
Sulpho Ditto		*pr*	*y*	Ag As S^4	53								
Hypo Ditto Ditto		*pr*	*y*	Ag As S^5	57								
Arseniate		*pr*	*br*	Ag As^2O^3	58·5						7·25	22·125†	
Sulpho Ditto		*pr*	*bn*	Ag As S O	45								
Chromate		*pr*	*r*	Ag Cr O^2	42·5						6·5	14·25†	
Molybdate		*fk*	*w*	Ag Mo O^2	47·5				*w*				
Sulpho Ditto		*fk*	*bk*	Ag Mo S^4O	55·5				*w*				
Hyper Ditto Ditto		*pr*	*bk*	Ag Mo S^5O	59·5				*w*				
Tungstate		*pr*	*w*	Ag W O	39·5				*w*				
Sulpho Ditto		*pr*	*bk*	Ag W S O	39·5								
Borate		*pr*	*w*	Ag B O^3	40·5								
Fluo Ditto		*pr*	*gy*	Ag B F O^3	45								

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											Acid.	Base.	Water.	
Carbonate		*pr*	*w*	$Ag^2C\ O^2$	70						2·75	14·75		
Bisulpho Ditto		*pr*	*bk*	$Ag\ C\ S^2$	38·5									
Cyanodide		*cd*	*w*	$Ag\ C\ Z$	34									
Sulpho Ditto	1	*pr*	*bk*	$Ag\ C\ Z\ S$	38									
Bisulpho	2	*pr*	*y*	$Ag\ C\ Z\ S^2$	42									
Ferro Ditto		*pr*	*bl*	$Ag\ C\ Z\ Fe$	41						1	2	3†	
Cyanate		*pr*	*w*	$Ag\ H\ C\ Z\ O$	38·25				*w*		1	1		
Fulminate		*cr*	*w*	$Ag\ H\ C\ Z\ O$	38·25	1·367			*w*					
Antimonite		*pr*	*w*	Ag^5Sb^3	170·5	9·820								
Antimoniate		*pr*	*w*	$Ag\ Sb^3O^5$	72·5									
Sulpho Ditto		*pr*	*y*	$Ag\ Sb\ S\ O^3$	46·5									
Tellurate		*pr*	*w*	$Ag\ Te\ O$	39·5									
Sulpho Ditto		*sd*	*gy*	$Ag\ Te\ S^2O$	47·5									
Tantalate		*pr*	*w*	$Ag\ Ta\ O$	46·5									
Fluo silicate		*cr*	*y*	$Ag\ Si^2T^3$	45					*d*				
Oxalate		*pr*	*w*	$Ag\ C\ O^2$	39·5				*w*		4·5	14·75†		
Potash Ditto		*cr*	*w*	$K\ Ag\ C\ O^2$	49				*w*					
Acetate		*nd*	*w*	$Ag\ H\ C\ O^3$	42·75				*w*		6·25	14·75†		
Lactate		*m*	*w*	$Ag\ H\ C^3O^4$	52·75				*w*					
Formate		*cr*	*w*	$Ag\ H\ C^2O^4$	45·25				*w*					
Mellate		*pr*	*w*	$Ag\ H\ C^4O^3$	51·75									
Potash Ditto		*m*	*w*	$K\ Ag\ H\ C^4O^3$	61·75									
Tartrate		*m*	*br*	$Ag\ H^2C^4O^5$	60				*w*		8·25	14·75†		
Citrate		*m*	*br*	$Ag\ H^6C^4O^6$	41·75						7·25	14·75†		
Malate	1	*gm*	*w*	$Ag\ H\ C^4O^4$	55·75									
	2	*cr*	*w*	$Ag\ H^2C^8O^8$	84									
Fungate		*pr*	*w*	$Ag\ H^2C^6O^3$	58									
Mucate		*pr*	*w*	$Ag\ H^2C^3O^4$	53									
Pyro Ditto		*sl*	*w*	$Ag\ H\ C^3O^4$	45·25									
Succinate		*pm*	*w*	$Ag\ H^2C^4O^3$	52				*w*					
Benzoate		*m*	*w*	$Ag\ H^3C^5O$	47				*w a*					
Meconate		*pr*	*w*	$Ag\ H^9C^8O^4$	72·25									
Boletate		*pr*	*w*	$Ag\ H\ C\ O$										
Camphorate		*pr*	*bl*	$Ag\ H^3C^2O$	38·25						45·845	54·155†		

Suberate		*pr*	*w*	Ag $H^4C\ O^2$	39·5					45·455	54·545†	
Pinate		*pr*	*bk*	Ag H^7C^7O	54·25				*a*			
Silvate		*gr*	*w*	Ag H C O					*a*			
Carbazotate		*nd*	*or*	Ag $H^2Z\ C^5O^7$	74·5							
Indigotate		*nd*	*r*	Ag H C^3O^2	48							
Sulpho napthalate		*m*	*bk*	Ag $H^6C^9S\ O^4$	76							
Pyro Ditto		*pr*	*w*	Ag $H^2C^4O^4$	56·25							
Potash Ditto		*pr*	*w*	K Ag $H^2C^4O^5$	70				*w a*			
COPPER		*sd*	*r*	Cu	8	8·953	2548	27				
Sulphited		*pr*	*br*	Cu^4S O	40							
Hypo Ditto		*pr*	*br*	Cu^4S^2O	44							
Sulphated		*pr*	*br*	$Cu^4S\ O^3$	48							
Selenited		*pr*	*r*	Cu^4Se	42							
Acetated		*pr*	*bn*	Cu^4H C O^3	47·25							
Vinated		*pr*	*br*	$Cu^4H\ C^2O^4$	54·25							
Pinated		*pr*	*br*	$Cu^4H^{12}C^{11}O^2$	76							
Silvated		*pr*	*bk*	Cu^4H C O								
Oxide	1	*pr*	*r*	Cu^4O	36	6·093				5	9	1·6825
	2	*pr*	*bk*	Cu^2O	20	6·401			*ac*			
	3	*pr*	*br*	Cu O	12							
Sulphite	1	*pm*	*gy*	Cu^2S	20	5·792			*w*			
	2	*cr*	*r*	Cu S	12					32·2	56·8	11
	3	*pr*	*bk*	Cu S^2	16							
	4	*pr*	*bn*	Cu^2S^3	28							
	5	*pr*	*br*	Cu S^5	28							
Potash Ditto		*cr*	*y*	K Cu S	22					85·2	14·8	
Sulphate	1	*pr*	*gn*	Cu S O^2	20					21·3	64·2	14·5
	2	*pm*	*bl*	Cu^2S O	24	2·2363				31·4	32·3	36·3
	3	*pm*	*bl*	$Cu^2S^2O^3$	36					5	5	5·625
	4	*cr*	*gn*	Cu S^2O^3	28					5	5	1·125
	5	*cr*	*bl*	$Cu^2S\ O^2$	20					10	5	
	6	*pr*	*bl*	Cu S^2O	20					5	20	3·375
	7	*pr*	*gn*	Cu S O	16					9	20	4·5
	8	*pr*	*gn*	Cu S^3O^6	44					5	15	2·25
Hypo Ditto		*pr*	*bl*	Cu S^2O^5	36					9	5	4·5
Potash Ditto	1	*cr*	*y*	K $Cu^2S^2O^2$	42	2·116			*w*	73·25	12·68	
	2	*pr*	*bn*	K Cu S^2O^2	34					30	16	4·5

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											Acid.	Base.	Water.	
Ammonia Ditto	1	*cr*	*gn*	Am Cu^2S O	28·5						20	7·125	14·625	
	2	*cr*	*gn*	Am^2Cu S O	20·5									
Hydro Carbo Ditto....		*pr*	*b*	Cu H C S^2O^5	39·25						1	2	1	
Nickel Ditto.....		*cr*	*gn*	Ni Cu S^2O^2	31						25·5	39·5	29·7	
Ferro Ditto.....	1	*pr*	*bn*	Fe Cu S^2O^2	31									
	2	*pr*	*bn*	Fe^2Cu S^2O^2	38						9·5	40	38·25	
Zinc Ditto.....		*pm*	*bl*	Zn Cu S^2O^2	32									
Magnesia Ditto.....		*pr*	*bn*	Mg Cu S^2O^2	27									
Hyponitrite.....		*pr*	*gn*	Cu Z O^2	19·5									
Nitrate	1	*pr*	*br*	Cu Z O^3	23·5	2·174			*w*	*d*	6·75	15†		
	2	*pr*	*bl*	Cu^3Z O^3	39·5						6·75	5†		
	3	*pr*	*bl*	Cu^4Z O^3	47·5						6·75	20†		
	4	*pr*	*bn*	Cu^5Z O^3	55·5						6·75	25†		
	5	*pr*	*bn*	$Cu^2Z^3O^5$	46·5						6·75	10†		
Ammonia Ditto.....		*pr*	*bk*	Am Cu Z O^3	28				*w*					
Chloride.....	1	*cr*	*gy*	Cu^2Cl	25				*ac*		40·2	59·8		
	2	*pm*	*y*	Cu Cl	17	1·68			*w*	*d*	26·42	73·58		
Ammonia Ditto.		*pr*	*gy*	Am^3Cu Cl	30·5									
Chloro hydrargyrate..		*nd*	*w*	Cu Mr Cl	42									
Chloro platinate...		*gm*	*gn*	Cu Pt Cl	33·5									
Chlorate.....		*m*	*gn*	Cu Cl O^5	29				*w*		1	1	3†	
Bromide.	1	*pm*	*gn*	Cu^2Bm^3	76				*w*	*d*	1	1	5†	
	2	*pr*	*w*	Cu Bm^2	48									
Iodide	1	*pm*	*br*	Cu^2I^3	112									
	2	*pr*	*br*	Cu I^2	72									
Iodate		*pr*	*or*	Cu I O^3	52									
Fluoride	1	*cr*	*bl*	Cu^2F^3	29·5				*w*					
	2	*pr*	*r*	Cu F^2	17				*w*					
Phosphite.	1	*pr*	*w*	Cu^2P^3	28						12	2†		
	2	*pr*	*y*	Cu P^2	16						4	2†		
	3	*pr*	*r*	Cu^3P^2	32						12	4†		
Phosphate.....	1	*gm*	*gn*	Cu^2P O^2	28	1·4158					35	49·5	15·5U	
	2	*pr*	*bk*	Cu H P^2O	20·25						4·5	10	1·125†	
	3	*pr*	*bl*	Cu P O^2	20						4·5	7·5	3·375†	

Phosphate	4	*sd*	*gn*	$Cu\ H\ P^3O$	24·25	4·205				4·5	15	3·375†
Selenite	1	*pr*	*bl*	Cu^2Se^3	44							
	2	*pr*	*gn*	$Cu\ Se^2$	34				*am*			
Arsenite	1	*pm*	*gn*	Cu^2As^3	42·5							
	2	*pr*	*gn*	$Cu\ As^2$	33							
Sulpho Ditto		*pr*	*gy*	$Cu\ As\ S^4$	25·5							
Hypo Ditto Ditto		*pr*	*gy*	$Cu\ As\ S^5$	29·5							
Arseniate	1	*pm*	*gn*	$Cu\ As^2O^3$	39					7·25	10	4·5†
	2	*pr*	*gn*	$Cu\ As^2O^4$	43					7·25	10	3·375†
	3	*pr*	*gn*	$Cu\ As\ O$	21·5					7·25	10	1·6825†
	4	*sd*	*gn*	$Cu^3As^2O^4$	59					7·25	10	2·25†
	5	*sd*	*gn*	$Cu\ As^4O^7$	74					7·25	5	5·625†
Sulpho Ditto		*pr*	*bk*	$Cu\ As\ S\ O$	25·5							
Chromate		*pr*	*br*	$Cu\ Cr\ O^2$	23					6·5	5	2·25†
Molybdate		*pr*	*gn*	$Cu\ Mo\ O^2$	28					9·5	40	38·25U
Sulpho Ditto		*pr*	*bn*	$Cu\ Mo\ S\ O^4$	40				*w*			
Hypo Ditto Ditto		*pr*	*r*	$Cu\ Mo\ S\ O^5$	44				*w*			
Tungstate		*pr*	*w*	$Cu\ W\ O^2$	24							
Sulpho Ditto		*pr*	*bn*	$Cu\ W\ S^2O$	28				*w*			
Boride ?				$Cu\ B\ O$								
Borate		*qm*	*gn*	$Cu\ B\ O^3$	21							
Fluo Ditto		*cr*	*bl*	$Cu\ B\ F^2O^3$	29							
Carbonate	1	*pr*	*r*	$Cu^2C^2O^3$	34					2·75	10†	
	2	*pm*	*or*	$Cu^3H\ C^2O^5$	42·25					2·75	7·75	·5625†
	3	*cr*	*gn*	$Cu\ H\ C^2O^3$	26·25	4·000				2·75	10	1·125†
Bisulpho Ditto		*pr*	*bk*	$Cu\ C^2S^2O^3$	34							
Potash Ditto		*cr*	*bl*	$K\ Cu\ C^2O^3$	36					11	26·25	
Ammonia Ditto		*cr*	*bl*	$Am\ Cu\ C^2O^3$	30·5							
Soda Ditto		*cr*	*bl*	$N\ Cu\ C^2O^3$	32							
Cyanodide	1	*pr*	*y*	$Cu\ Z\ C$	14·5					1	1	
	2	*pl*	*w*	$Cu^2Z\ C$	22·5					2	3	
Sulpho Ditto		*pr*	*gn*	$Cu\ C\ Z\ S$	18·5							
Ferro Ditto		*pr*	*bn*	$Cu\ Z\ Fe\ C$	21·5				*ac*			
Cyanate		*pr*	*bn*	$Cu\ H\ Z\ C\ O^2$	22·75				*w*			
Hydrosulpho Ditto		*pr*	*w*	$Cu\ H^2Z\ C\ S\ O^2$	27							
Fulminate	1	*fk*	*bn*	$Cu^2H\ C\ Z\ O$	26·75							
	2	*cr*	*gn*	$Cu\ H\ C^2Z\ O^2$	25·75							
	3	*pm*	*w*	$Cu^2H\ C^2Z\ O^3$	37·75							
Antimonite		*pr*	*vi*	$Cu^2Sb^6O^5$	102							
Antimoniate		*pr*	*gn*	$Cu\ Sb^3O^3$	53							

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											Acid.	Base.	Water.	
Sulpho Ditto		*pr*	*bk*	$Cu\ Sb^{3}S^{2}O^{3}$	61									
Tellurate		*pr*	*gn*	Cu Te O	20									
Sulpho Ditto	1	*sd*	*gy*	$Cu^{2}Te\ S\ O$	32									
	2	*sd*	*bn*	Cu Te S O	24									
Fluo titaniate		*pr*	*w*	$Cu\ Ti^{2}F^{3}$	27·5									
Silicate	1	*sd*	*gn*	$Cu^{2}H\ Si\ O$	24·25									
	2	*pr*	*r*	$Cu\ H\ Si^{2}O^{3}$	24·25						3	5	1·125†	
Fluo Ditto		*pr*	*r*	$Cu\ Si^{2}F^{3}$	25·25			3			4	5	2·25†	
Oxalate		*cr*	*r*	$Cu\ C\ O^{2}$	19				*w*		4·5	5	1·125†	
Potash Ditto	1	*pm*	*r*	$K\ Cu\ C\ O^{2}$	29				*w*	*ef*	36·46	20·5	18·25	
	2	*pm*	*or*	K Cu C O	25						40·5	22·5	29	
Ammonia Ditto	1	*pl*	*gy*	$Am\ Cu\ C\ O^{2}$	23·5				*w*	*ef*	47·5	25	27·5	
	2	*pm*	*gn*	Am Cu C O	19·5						36	39	24·40	
	3	*pr*	*r*	$Am\ Cu^{2}C\ O$	27·5				*w*		43	45·6	10·80	
Soda Ditto		*pm*	*gy*	N Cu C O	21						8·5	9·5	2·25†	
Acetate	1	*pr*	*gn*	$Cu^{2}H\ C\ O^{3}$	31·25	1·78					6·25	10	6·75†	
	2	*pm*	*gn*	$Cu\ H\ C\ O^{3}$	23·25	1·914			*w*		6·25	5	1·25†	
	3	*cr*	*bl*	$Cu^{3}H\ C^{2}O^{3}$	42·25						6·25	7·5	3·375†	
	4	*sl*	*bl*	$Cu^{4}H\ C^{2}O^{5}$	50·25						6·25	15	2·25†	
Ammonia Ditto		*cr*	*bl*	$Am\ Cu\ H\ C\ O^{3}$	27·75					*ef*				
Calcareo Ditto		*pm*	*bl*	$Ca\ Cu\ H\ C\ O^{3}$	28·25						28	10	19·4	
Lactate		*pr*	*bn*	$Cu\ H\ C^{3}O^{4}$	33·25									
Formate	1	*pm*	*gn*	$Cu\ H\ C^{2}O^{3}$	26·25	1·815			*w*		32·7	35·4	31·9U	
	2	*pr*	*gn*	$Cu\ H\ C^{2}O^{3}$	34·25									
Mellate		*cr*	*bl*	$Cu\ H\ C^{4}O^{3}$	26·25									
Potash Ditto		*pr*	*bl*	$K\ Cu\ H\ C^{4}O$	36·25									
Tartrate	1	*cr*	*gn*	$Cu\ H^{2}C^{4}O^{5}$	40·5						9·25	5	3·375	
	2	*pr*	*w*	$Cu^{2}H^{2}C^{4}O^{5}$	48·5									
Pyro Ditto		*pr*	*w*	$Cu\ H^{3}C^{4}O^{4}$	36·75						62·24	37·76U		
Potash Ditto		*cr*	*bl*	$K\ Cu\ H^{2}C^{4}O^{5}$	50·5									
Soda Ditto		*pr*	*gn*	$N\ Cu\ H^{2}C^{4}O^{5}$	46·5									
Sulpho Ditto		*pr*	*gn*	$Cu\ H\ C^{4}S^{2}O^{8}$	60·25									
Vinate		*tb*	*bl*	$Cu\ H^{2}C^{4}O$	24·5									
Citrate		*cr*	*gn*	$Cu\ H^{6}C^{4}O^{6}$	45·5									

Malate	1	*m*	*gn*	Cu H $C^{1}O^{1}$	36·25							
	2	*m*	*gn*	$Cu^{2}H$ $C^{4}O^{4}$	44·25							
Fungate		*pr*	*gn*	Cu $H^{2}C^{6}O^{5}$	38·5							
Mucate	1	*pr*	*gn*	Cu $H^{5}C^{6}O^{8}$	59·25					13	10†	
	2	*pr*	*gn*	$Cu^{2}H^{5}C^{6}O^{8}$	67·25							
Pyro Ditto		*cr*	*bl*	Cu $H^{3}C^{5}O^{6}$	59·5							
Succinate	1	*pr*	*bl*	Cu $H^{2}C^{4}O^{3}$	32·5							
	2	*pr*	*bl*	$Cu^{2}H^{2}C^{4}O^{3}$	40·5							
Benzoate		*cr*	*bl*	Cu $H^{5}C^{14}O^{3}$	63·25							
Gallate		*fk*	*br*	Cu $H^{3}C^{7}O^{4}$	30·75							
Meconate		*pr*	*y*	Cu $H^{3}C^{9}O^{4}$	53·25							
Boletate		*nd*	*bl*	Cu H C O					*w*			
Camphorate		*pr*	*gn*	Cu $H^{3}C^{2}O$	18·75					70·418	29·582†	
Suberate		*pr*	*gn*	Cu $H^{4}C$ O^{2}	20					71·25	28·75†	
Butyrate		*pm*	*bl*	Cu $H^{9}C^{8}O^{5}$	54·25					9·625	10	2·25†
Cholesterate		*pr*	*gn*	Cu $H^{7}C^{6}O$	31·75							
Pinate		*pr*	*gn*	Cu $H^{12}C^{11}O^{2}$	52					100	7·5	
Silvate		*gm*	*bl*	Cu H C O								
Carbazotate		*cr*	*gn*	Cu $H^{2}C^{5}O^{5}$	50				*d*			
Pyrurate		*pr*	*bl*	Cu $Z^{2}H^{6}C^{9}O^{62}$	67·5							
Sulpho naphthalate		*cr*	*bl*	Cu $H^{6}C^{8}S$ O^{4}	56·5							
Sinapate		*pr*	*w*	Cu Z $H^{9}C^{3}O^{4}$	42·75							
URANIUM		*sd*	*or*	U	35	7·500						
Oxide	1	*pr*	*gn*	U O	39							
	2	*gr*	*bk*	U O^{2}	43							
Acid		*ld*	*y*	U O	39							
Sulphite	1	*pr*	*bk*	U S	39							
	2	*pr*	*bk*	$U^{2}S^{3}$	82							
Sulphate	1	*pl*	*gn*	$U^{3}S$ O^{2}	117					7·5	28	4·5†
	2	*pm*	*y*	U S O^{2}	47				*w a*	18	70	12
Potash Ditto	1	*pr*	*gn*	$K^{2}U^{3}S^{5}O^{10}$	185							
	2	*pr*	*y*	K U S O^{2}	57					35·5	11	4·5†
Ammonia Ditto		*pr*	*y*	Am U S O^{2}	51·5							
Nitrate	1	*pr*	*y*	$U^{2}Z$ O^{3}	85·5				*w a*	10·125	28	19·125†
	2	*pr*	*y*	U Z O^{3}	50·5				*w a*	25	61	14
Chloride		*pl*	*y*	U Cl	44				*w*	*d*		
Fluoride		*pr*	*w*	U F^{5}	83·5				*w*			

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											Acid.	Base.	Water.	
Potash Ditto		*pr*	*y*	K U^{2}F^5	93·5				*w*					
Phosphite		*pr*	*w*	U^{2}P^3	78				*w*					
Phosphate	1	*fl*	*w*	U^{2}P O	78									
	2	*pr*	*w*	U P^{2}O	47									
	3	*pr*	*y*	U P O^2	47						6·75	28	10·125†	
Calcareo Ditto		*cr*	*w*	Ca U P O^2	53						65·5	7·95	13·5†	
Selenite	1	*pr*	*y*	U^{2}Se^5	100									
	2	*cr*	*w*	U Se^2	55									
Arsenite		*pr*	*y*	U^{2}As^5	98·5									
Sulpho Ditto		*m*	*br*	U As S^4	60·5									
Hypo Ditto Ditto		*pr*	*br*	U As S^5	64·5									
Arseniate		*pr*	*y*	U As O^5	56·5									
Sulpho Ditto		*pr*	*y*	U As S^{2}O	56·5									
Chromate	1	*pr*	*or*	U^{2}Cr O^2	85									
	2	*pr*	*or*	U Cr^{2}O^2	57									
Molybdate	1	*pr*	*y*	U^{2}Mo O^2	90									
	2	*pr*	*y*	U Mo^{2}O^2	57									
Sulpho Ditto		*pr*	*bn*	U Mo S^{2}O^2	63									
Tungstate		*pr*	*y*	U W O^2	51									
Sulpho Ditto		*pr*	*bk*	U W S^{2}O^2	59									
Borate		*pr*	*y*	U B O^2	44									
Carbonate	1	*pr*	*gn*	U^{2}C O^3	85									
	2	*pr*	*y*	U^{2}C^{2}O^5	88									
Bisulpho Ditto		*pr*	*gy*	U^{2}C S^{2}O^3	93									
Potash Ditto		*cr*	*r*	K U C O^3	60									
Ammonia Ditto	1	*pm*	*y*	Am U C O^3	54·5				*w*		30·75	4	14·625†	
	2	*cr*	*gn*	Am^{2}U C O^3	59									
Cyanodide		*pr*	*r*	U C Z	41·5									
Sulpho Ditto		*pr*	*y*	U C Z S	45·5				*w*					
Ferro Ditto		*pr*	*r*	U C Z Fe	48·5									
Sulpho Tellurate		*pr*	*bk*	U Te S^{2}O	55									
Oxalate	1	*gr*	*w*	U C O^2	46						4·5	28	3·375†	
	2	*pr*	*w*	U C^{2}O^4	57						13·5	28†		
Acetate		*pm*	*y*	U H C O^3	50·25				*w*					

Tartrate		*gr*	*y*	U $H^2C^4O^5$	67·5				*w*					
Pyro Ditto		*cr*	*w*	U $H^2C^4O^4$	63·75				*w*					
Citrate		*pr*	*y*	U $H^6C^4O^6$	72·5				*w*					
Malate		*pr*	*y*	U H C^4O^4	61·25				*w*					
Succinate		*pr*	*y*	U $H^2C^4O^3$	59·5				*w*					
Benzoate		*pr*	*y*	U $H^5C^{14}O^3$	90·25				*w*					
Gallate		*pr*	*br*	U $H^{14}C^6O^8$	86									
Camphorate		*pr*	*y*	U H^3C^2O	45·75									
Suberate	1·	*pr*	*y*	U H^4C O^2	47									
	2	*pr*	*w*	U^2H^4C O^2	82							18·75	28†	
Pinate		*ld*	*br*	U $H^{12}C^{11}O^2$	79									
BISMUTH		*sd*	*w*	Bi	18	9·833	476							
Oxide	1	*pr*	*y*	Bi^2O	40									
	2	*pr*	*w*	Bi O	22	8·449								
	3	*pr*	*bk*	Bi O^2	26	8·211								
Hydrate		*cr*	*bk*	Bi H O	22·25									
Sulphite	1	*pr*	*gy*	Bi^2S	40				*w*			100	197·5U	
	2	*pr*	*gn*	Bi S	22	7·591								
	3	*pr*	*y*	Bi S^2	26	6·549								
Sulphate	1	*cr*	*w*	Bi S O^2	30							5	10†	
	2	*pr*	*w*	Bi^3S O^3	70							5	50†	
Nitrate	1	*pm*	*y*	Bi^2Z O^5	51·5				*w*	*d*		34·2	48·8	17U
	2	*pr*	*y*	Bi Z O^3	33·5							6·75	10	3·375†
	3	*pr*	*w*	Bi Z^2C^5	45							6·75	10†	
	4	*pr*	*y*	Bi Z O^3	37							6·75	20	2·25†
	5	*cr*	*w*	$Bi^2Z^2O^5$	65							6·75	40	2·25†
Chloride		*pm*	*w*	Bi Cl	27									
Bromide		*pr*	*gy*	Bi^2Bm^3	96									
Iodide		*pr*	*o*	Bi^2I^3	132									
Fluoride		*pr*	*y*	Bi^2F^3	49·5									
Phosphoret		*pr*	*bk*	Bi P	22									
Phosphate		*cr*	*w*	Bi P O^2	30				*w*			4·5	10	3·375†
Selenite		*cr*	*w*	Bi^2Se^3	66									
Arsenite		*pr*	*w*	Bi^2As^3	55·5									
Sulpho Ditto		*pr*	*gy*	Bi As S^4	43·5									
Hypo Ditto Ditto		*pr*	*gy*	Bi As S^5	47·5									
Arseniate		*pr*	*w*	$Bi As^2O^3$	49							7·25	10	2·25†

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											Acid.	Base.	Water.	
Sulpho Arseniate		*pr*	*bn*	Bi As S O	35·5									
Chromate		*pr*	*y*	Bi Cr O^2	33						6·5	10	2·25†	
Molybdate		*pr*	*y*	Bi Mo O^2	38				*w*					
Sulpho Ditto		*pr*	*bn*	Bi Mo S^4O	50				*w*					
Hyper Ditto Ditto		*pr*	*bn*	Bi Mo S^5O	54				*w*					
Sulpho Tungstate		*pr*	*br*	Bi W S^2O	30				*w*					
Borate		*pr*	*w*	Bi B O^3	31									
Carbonate	1	*pr*	*w*	Bi^2C O^3	51						7·5	86·2	6·3U	
	2	*pr*	*w*	Bi C O^3	33									
	3	*pr*	*w*	Bi C^3O^6	39						2·75	30	2·25	
Bisulpho Ditto		*pr*	*bn*	Bi C S^2O	33									
Cyanodide		*pr*	*y*	Bi C Z	24·5									
Sulpho Ditto		*pr*	*y*	Bi C Z S	28·5									
Ferro Ditto		*pr*	*y*	Bi C Z Fe	31·5									
Tellurate		*pr*	*w*	Bi Te O	30									
Sulpho Ditto		*pr*	*bn*	Bi Te S O	34									
Silicate		*gs*	*y*	Bi Si O	24									
Oxalate		*pr*	*w*	Bi C O^3	33						4·5	10†		
Acetate		*cr*	*w*	Bi H C O^3	33·25				*w*					
Formate		*cr*	*w*	Bi H C^2O^3	36·25				*w*					
Tartrate		*pr*	*w*	Bi $H^2C^4O^5$	50·5						8·25	10	5·625†	
Succinate		*pl*	*y*	Bi $H^2C^4O^3$	42·5									
Benzoate		*pr*	*w*	Bi $H^5C^{14}O^3$	73·25				*w a*					
Gallate		*pr*	*bn*	Bi H $C^{14}O^6$	71·5									
Croconate		*pr*	*y*	Bi H C^5O^4	49									
Pinate		*pr*	*w*	Bi $H^{12}C^{11}O^2$	62						69·93	10		
TIN		*sd*	*w*	Sn	14·5	7·285	442							
Oxide	1	*pr*	*bk*	Sn^2O	33									
	2	*pr*	*y*	Sn O^2	22·5									
Sulphate Ditto		*pr*	*y*	Sn S O^4	34·5									
Nitrate Ditto		*pr*	*w*	Sn Z O^4	34									

Iodate Ditto		*pr*	*vi*	Sn I O^4	62·5							
Selenite Ditto		*pr*	*w*	Sn Se O^4	40·5							
Antimoniate Ditto		*pr*	*w*	Sn Sb O^4	41·5							
Chromate Ditto		*pr*	*or*	Sn Cr O^4	37·5							
Molybdate Ditto		*pr*	*w*	Sn Mo O^4	42·5							
Acetate Ditto		*pr*	*w*	Sn H C O^5	37·75							
Succinate Ditto		*pr*	*w*	Sn $H^2C^4O^5$	47							
Pinate Ditto		*pr*	*w*	Sn $H^{12}C^{11}O^4$	66·5							
	3	*pr*	*gy*	Sn^2O^3	41							
	4	*pr*	*gy*	Sn O	18·5							
Hydrate	1	*pr*	*w*	Sn H^2O^3	27							
	2	*pr*	*w*	Sn H O	18·75							
Sulphite	1	*pr*	*gy*	Sn S	18·5	7·554						
	2	*pr*	*y*	Sn S^2	22·5							
	3	*pr*	*or*	Sn^2S^3	41							
Hypo Ditto		*ld*	*y*	Sn^2S	33				*w*			
Sulphate	1	*nd*	*w*	Sn S O^2	26·5				*w*			
	2	*gm*	*w*	Sn^3S O^3	45							
Nitrate	1	*ld*	*y*	Sn Z O^3	30							
	2	*ld*	*w*	Sn^2Z O^3	44·5							
Ammonia Ditto		*ld*	*w*	Am Sn Z O^3	34·5				*w*			
Chloride	1	*pm*	*w*	Sn Cl	23·5					1	1	3†
	2	*pm*	*w*	Sn^2Cl	38					14·5	4·5†	
	3	*cr*	*w*	Sn Cl^2	32·5					9	7·125†	
Chloro stannate		*pr*	*w*	Sn Sn Cl^3	55					2	1	1†
Bromide	1	*pr*	*w*	Sn^2Bm^3	69							
	2	*pr*	*w*	Sn Bm^2	54·5							
Iodide	1	*pr*	*vi*	Sn^2I^3	125							
	2	*pr*	*vi*	Sn I^2	78·5							
Iodate		*pr*	*w*	Sn I O^3	58·5							
Fluoride	1	*pm*	*w*	Sn^2F^3	42·5				*w a*			
	2	*pm*	*w*	Sn F^2	23·5				*w a*			
Phosphite		*pr*	*w*	Sn^2P^3	41					3·5	8·25	·5625
Phosphate		*pr*	*w*	Sn P O^2	26·5							
Selenite		*sd*	*w*	Sn^2Se^3	59							
Arsenite		*sd*	*w*	Sn^2As^3	57·5		520					
Sulpho Ditto	1	*pr*	*br*	Sn As S	40							
	2	*pr*	*y*	Sn^2As S	54·5							
Hypo Ditto Ditto		*pr*	*or*	Sn As S^5	44							

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											Acid.	Base.	Water.	
Arseniate	1	*pr*	*w*	Sn As^2O^3	45·5									
	2	*pr*	*w*	$Sn^2As^2O^3$	60									
Sulpho Ditto	1	*pr*	*bn*	Sn As S O	32									
	2	*pr*	*y*	Sn As S^2O	36									
Chromate	1	*fk*	*bn*	$Sn^2Cr\ O^2$	44									
	2	*fk*	*y*	Sn Cr^2O^2	36·5									
Molybdate		*pr*	*w*	Sn Mo O^2	34·5									
Sulpho Ditto	1	*pr*	*bk*	$Sn^2Mo\ S^4O$	61				*w*					
	2	*pr*	*gy*	Sn Mo S^4O	46·5				*w*					
Hyper Ditto Ditto		*ld*	*r*	Sn Mo S^5O	50·5				*w*					
Tungstate		*pr*	*y*	Sn W O^2	30·5									
Sulpho Ditto	1	*fk*	*bn*	Sn W S O^2	34·5				*w*					
	2	*fk*	*gy*	Sn W S^2O^2	38·5				*w*					
Borate		*pr*	*w*	Sn B O^3	27·5									
Carbonate		*pr*	*w*	$Sn^2C\ O^2$	44									
Bisulpho Ditto	1	*pr*	*bn*	$Sn^2C\ S^2O$	44									
	2	*pr*	*y*	Sn C S O	25·5									
Cyanodide		*pr*	*w*	Sn C Z	21				*w*					
Sulpho Ditto		*pr*	*w*	Sn C Z S	25				*w*					
Ferro Ditto		*pr*	*w*	Sn C Z Fe	28									
Antimonite		*sd*	*w*	Sn^2Sb	54·5	7·059								
Antimoniate		*pr*	*w*	Sn Sb^2O^3	59·5									
Tellurate		*pr*	*y*	Sn Te O	26·5									
Sulpho Ditto	1	*sd*	*y*	$Sn^2Te\ S\ O$	45									
	2	*sd*	*bn*	Sn Te S O	30·5									
Fluo Silicate		*pm*	*w*	Sn Si^2F^3	30·5				*w*					
Oxalate		*pm*	*bn*	Sn C O^2	25·5				*w*					
Croconate		*pr*	*w*	Sn C O	29·5									
Acetate	1	*gm*	*w*	Sn $H^2C^2O^3$	33				*w*					
	2	*cr*	*w*	$Sn^2H\ C\ O^3$	44·75									
Lactate		*cr*	*w*	Sn H C^3O^4	39·75									
Formate		*pr*	*bk*	Sn H C^2O^3	32·75				*w*					
Tartrate		*nd*	*w*	Sn $H^2C^4O^5$	47				*w*					
Potash Ditto		*l*	*w*	K Sn $H^2C^4O^5$	57				*w*					

Vinate		*pm*	—	Sn H^2C^4O	34			*w*				
Malate		*pr*	*w*	Sn H C^4O^4	42·75			*w*				
Succinate	1	*cr*	*w*	Sn H C^2O^3	39			*w*				
	2	*cr*	*w*	$Sn^2H^2C^4O^3$	53·5							
Benzoate		*pr*	*w*	Sn $H^5C^{14}O^3$	69·75			*w*				
Camphorate		*pr*	*w*	Sn H^2C^2O	25·25							
Suberate		*pr*	*w*	Sn H^4C O^2	26·5							
Pinate	1	*pr*	*w*	$Sn^2H^{12}C^{11}O^2$	73				100	12·1		
	2	*pr*	*w*	Sn $H^{12}C^{11}O^2$	58·5							
LEAD		*sd*	*bl*	Pb	26	11·3523	376					
Oxide	1	*pr*	*y*	Pb^2O	56	7·568						
	2	*pr*	*br*	Pb O^2	34	8·902						
	3	*pr*	*r*	Pb^4O^3	116							
	4	*pr*	*br*	Pb O	30							
Sulphite	1	*pr*	*gy*	Pb^2S	56				22·2	77·8U		
	2	*pr*	*gy*	Pb S	30				4	14†		
	3	*pr*	*gy*	$Pb^2S^2O^3$	72				29·7	70·3U		
	4	*pr*	*gy*	Pb S^5	46							
Hypo Ditto Ditto		*pr*	*w*	Pb^2S^5	72				5	14†		
Sulphate	1	*pr*	*w*	Pb S^2O	38	1·874			5	14†		
	2	*pr*	*w*	Pb^2S O^2	64	6·3						
	3	*cr*	*w*	Pb S^2O	38							
	4	*pr*	*w*	Pb^2S O^2	64							
	5	*pr*	*w*	Pb^2S O	60							
Hypo Ditto Ditto	1	*ld*	*w*	Pb S O	34				9	14	4·5†	
	2	*sd*	*w*	Pb^2S O^2	64							
Vegeto Ditto		*ld*	*w*	Pb H C S^4O^6	69·25				9	14	22·75†	
Hyponitrite	1	*pm*	*y*	Pb Z O^2	37·5			*w*	4·75	14	1·125†	
	2	*sl*	*w*	Pb Z O	33·5			*w a*	4·75	28	2·25†	
	3	*cr*	*w*	Pb Z^2O	37			*w a*	4·75	56	1·125†	
Nitrate	1	*sl*	*w*	Pb Z O^3	41·5				100	412U		
	2	*pm*	*w*	Pb^2Z O^3	67·5	4·0		*w*	6·75	84	1·125†	
	3	*pr*	*w*	Pb Z^2O^3	45				6·75	28†		
	4	*cr*	*w*	$Pb^2Z^2O^5$	71	4·018		*w a*	6·75	14†		
	5	*pr*	*w*	Pb Z O^3	33·5				6·75	42	1·6875†	
Chloride	1	*pr*	*w*	Pb Cl	35	1·823		*w*	24·83	75·17U		
	2	*pr*	*y*	Pb^2Cl^2	70							

Name of the Element, and its Combinations.		Form.	Colour.	Symbols of the Components, and their Quantities.	Atom. Wt. and Numbers. Equivalent Hyd. = 25.	Specific Gravity Water = 1·000.	Fusibility, Fahrenheit.	Fusibility, Wedgwood.	Solubility.	Atmospheric Action.	Theoretic Composition.			Trivial Name.
											Acid.	Base.	Water.	
Ammonia Ditto.....		*pr*	*w*	Am Pb Cl	39·5									
Chloro hydrargyrate..		*pm*	*w*	Pb Cl Mr O	60									
Chlorate		*pl*	*w*	Pb Cl O	39									
Bromide.....		*pr*	*w*	Pb^2Am^5	112									
Iodide.....		*cr*	*y*	Pb^2I^5	148									
Iodate..		*pr*	*or*	Pb I O^3	70									
Fluoride.....		*pl*	*w*	Pb^2F^3	65·5									
Phosphite.....		*pr*	*w*	Pb^2P^3	64						3·5	14	·5625†	
Phosphate	1	*pr*	*w*	Pb^2P O	60						4·5	.21†		
	2	*pr*	*w*	Pb P^2O^2	42						6·75	14†		
	3	*pr*	*w*	Pb P O	34						4·5	14†		
	4	*pr*	*w*	Pb P O^2	38						4·5	16·8†		
Nitro Ditto.....		*cr*	*w*	Pb Z P O^2	41·5						20·75	37U		
Selenite.....		*pr*	*gy*	Pb^2Se^3	82						7	14†		
Arsenite.....	1	*pr*	*br*	Pb^2As^3	80·5						6·25	14†		
	2	*pr*	*w*	Pb As^2	45						12·5	14†		
Sulpho Ditto...		*pr*	*bn*	Pb As S^4	51·5		350							
Hypo Ditto Ditto.....		*pr*	*gy*	Pb As S^5	55·5									
Arseniate	1	*pr*	*w*	Pb^2As O^2	69·5						7·25	14†		
	2	*pr*	*gy*	Pb As^2O^2	53						7·25	21†		
Sulpho Ditto.....		*pr*	*r*	Pb As S^2O^2	51·5									
Chromate.....	1	*pr*	*or*	Pb^2Cr O^2	67	6·0					6·5	14†		
	2	*pm*	*or*	Pb Cr^2O	44						6·5	28†		
Molybdate		*pm*	*w*	Pb Mo O^2	46	5·7					9	14†		
Sulpho Ditto		*cb*	*y*	Pb Mo S^4O	58									
Hyper Ditto Ditto.....		*pr*	*bn*	Pb Mo S^5O	62				*w*					
Tungstate	1	*pr*	*br*	Pb W O^2	38						15·5	14†		
	2	*pr*	*br*	Pb W^2O^2	45						31	14†		
Sulpho Ditto.....		*pr*	*bn*	Pb W S O	42				*w*					
Borate.....		*pr*	*w*	Pb B O	31									
Fluo Ditto.....		*tb*	*w*	Pb B F O	35·5				*w a*					
Carbonate.....	1	*cr*	*w*	Pb^2C O^5	67	7·24					2·75	14†		
	2	*pr*	*w*	Pb C O^5	41									
Bisulpho Ditto.....		*pr*	*bk*	Pb C S^2O	41									

Cyanodide		*pr*	*w*	Pb C Z	32·5				*w*				
Sulpho Ditto	1	*pr*	*w*	Pb C Z S	36·5				*w*	*d*			
	2	*pr*	*y*	Pb C Z S^2	40·5								
Ferro Ditto		*pr*	*w*	Pb C Z Fe	39·5						1	2	3
Cyanate		*pr*	*w*	Pb H C Z O^2	40·75								
Fulminate		*sc*	*w*	Pb H C Z O	36·75								
Antimonite		*sd*	*gy*	Pb Sb									
Sulpho Ditto	1	*pr*	*w*	Pb Sb S									
	2	*pr*	*w*	Pb Sb S									
Hypo Ditto Ditto	1	*pr*	*w*	Pb Sb S									
	2	*pr*	*w*	Pb Sb S^2									
	3	*pr*	*w*	Pb Sb S^3									
	4	*pr*	*w*	Pb Sb S^4									
	5	*pr*	*w*	Pb Sb S^5									
Antimoniate		*pr*	*w*	Pb Sb^2O^3	60								
Sulpho Ditto		*pr*	*y*	Pb Sb S^2O	45								
Tellurate		*pr*	*w*	Pb Te O	38						10	14†	
Sulpho Ditto		*sd*	*gy*	Pb Te S O	42								
Fluo tantalate		*pr*	*w*	Pb Ta^2F^3	69·5				*w*				
Fluo titaniate		*cr*	*w*	Pb Ti^2F^3	45·5				*w*				
Silicate		*pr*	*w*	Pb Si O	32								
Fluo Ditto		*m*	*bl*	Pb Si^2F^3O	45·5				*w*				
Uraniate		*pr*	*y*	$Pb^5U^3O^4$	251				*w*				
Oxalate		*gr*	*w*	Pb C O^2	37						4·5	14†	
Potash Ditto	1	*nd*	*y*	K Pb C O^2	47					*ef*	10·5	9·5	4·5
	2	*cr*	*gn*	K Pb C^2O^4	54						10·5	9·5	2·25
Acetate	1	*pm*	*w*	Pb H C O^3	41·25	2·345			*w*		7	14	3·375U
	2	*pl*	*w*	Pb H^2C O^3	41·5	2·575			*w a*		6·25	84	3·375†
	3	*cr*	*w*	$Pb^2H^2C^2O^5$	78·5						6·25	14	3·345†
	4	*sl*	*w*	Pb^2H C O^5	67·25						6·25	28	1·125†
	5	*cr*	*w*	Pb^2H C^2O^3	70·25						6·25	42†	
Lactate	1	*pr*	*br*	Pb H C^3O^4	51·25				*w*		17	83U	
	2	*gr*	*br*	Pb $H^2C^3O^4$	58·5				*w*				
	3	*gm*	*y*	Pb $H^6C^5O^3$	74·5				*w*				
Formate		*sd*	*w*	Pb H C^2O^3	44·25						4·625	14	1·125†
Mellate		*pr*	*w*	Pb H C^4O^3	50·25						32·95	67·05†	
Tartrate		*pr*	*w*	Pb $H^2C^4O^5$	58·5						8·25	14†	
Pyro Ditto		*cr*	*w*	Pb $H^3C^4O^4$	54·75						37·5	62·5U	
Potash Ditto		*pr*	*w*	K Pb $H^2C^4O^5$	68·5						37·5	14†	
Vinate		*nd*	*w*	Pb H^2C^4O	42·5				*w*		44·395	55·605†	

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											Acid.	Base.	Water.	
Sulpho Vinate		*m*	*w*	Pb H $C^4S^2O^8$	52·25				*w a*					
Citrate		*cr*	*w*	Pb $H^6C^4O^6$	63·5						7·25	14†		
Pyro Ditto		*gm*	*w*	Pb $H^{10}C^6O^9$	82·5				*w*		33·4	66·6†		
Malate	1	*fk*	*w*	Pb H C^4O^4	54·25									
	2	*cr*	*w*	Pb $H^2C^3O^3$	47·5									
	3	*ld*	*w*	Pb H C^4O^3	50·25				*w*					
	4	*pr*	*w*	Pb H C O	33·25									
Pyro Ditto		*nd*	*w*	Pb $H^2C^6O^4$	60·5				*w*					
Ammonia Ditto		*cr*	*w*	Am Pb $H^2C^4O^4$	65				*w*					
Zinc Ditto		*pr*	*w*	Zn Pb $H^2C^6O^4$	68·5									
Fungate		*pr*	*w*	Pb $H^2C^6O^3$	56·5									
Mucate		*pr*	*w*	Pb $H^2C^6O^8$	58·5						13	14†		
Pyro Ditto		*m*	*w*	Pb $H^2C^9O^6$	67·5									
Succinate	1	*cr*	*w*	Pb $H^2C^4O^2$	50·5						6·25	14†		
	2	*pl*	*w*	$Pb^2H^2C^4O^3$	76·5				*w*		15	14	1·125†	
Benzoate	1	*pr*	*w*	Pb $H^5C^{14}O^3$	81·25				*w*		49·66	46·49	3·85U	
	2	*cr*	*w*	$Pb^2H^5C^{14}O^3$	103·25						26	74		
Meconate		*fk*	*w*	Pb $H^3C^9O^4$	71·25									
Gallate	1	*pr*	*w*	Pb $H^7C^3O^4$	52·75						8	14		
	2	*pr*	*w*	$Pb^2H^7C^3O^4$	78·75						8	42		
Kinate	1	*cr*	*w*	Pb $H^4C^2O^4$	52									
	2	*cr*	*w*	$Pb^2H^4C^5O^4$	84									
Boletate		*pr*	*w*	Pb H C O										
Camphorate		*pr*	*w*	Pb H^3C^2O	36·75				*w*		45·89	54·11		
Suberate		*pr*	*w*	Pb H^4C O^2	38									
Stearate	1	*sd*	*w*	Pb $H^{15}C^{14}O$	75·75									
	2	*pr*	*w*	$Pb^2H^{15}C^{14}O$	101·75									
Margarate	1	*sd*	*w*	Pb $H^{13}C^7O$	54·75									
	2	*pr*	*w*	$Pb^2H^{13}C^7O$	80·75									
Oleate		*ld*	—	$Pb^2H^{33}C^{14}O$	98·75									
Phocenate	1	*pl*	—	Pb H C O					*w*					
	2	*nd*	—	Pb H C O										
Butyrate	1	*nd*	*w*	Pb $H^{11}C^8O^3$	60·75									
	2	*sd*	*w*	$Pb^2H^{11}C^8O^3$	86·75				*w*					

Cholesterate		*pr*	*w*	Pb H C O						23	73†	
Pinate		*pr*	*w*	Pb $H^{11}C^{12}O^{2}$	70					34	66†	
Indigotate	1	*cr*	*y*	Pb Z $C^{3}O^{2}$	46·5					100	19·5†	
	2	*nd*	*y*	Pb $Z^{2}C^{5}O^{2}$	50					100	57·3†	
	3	*nd*	*y*	Pb $Z^{2}C^{3}O^{3}$	54					100	52·4†	
	4	*pr*	*or*	Pb $Z^{2}C^{15}O^{10}$	118					100	103·4†	
	5	*pr*	*y*	$Pb^{2}Z^{2}C^{15}O^{10}$	144					100	59·7†	
Pyrurate		*pr*	*w*	Pb Z $H^{2}C^{2}O$	40							
Nitro saccharate		*gm*	*y*	Pb Z H C O								
Allentoate		*ld*	*y*	Pb $H^{8}C^{5}O^{4}$	73							
Sulpho naphthalate		*sd*	*w*	Pb $H^{6}C^{9}S$ O^{4}	74·5			*w a*				
Sinapate		*pr*	*w*	Pb Z $H^{9}C^{5}O^{4}$	56·75							
CERIUM		*sd*	*gy*	Ce	11·5	4·619						
Oxide	1	*pr*	*w*	$Ce^{2}O^{3}$	35							
	2	*pr*	*w*	Ce O	15·5							
	3	*pr*	*y*	Ce O^{2}	19·5							
Hydrate		*pr*	*br*	Ce H O^{2}	19·75							
	4	*pr*	*w*	$Ce^{4}O^{3}$	58							
	5	*pr*	*y*	$Ce^{2}O^{2}$	42·5							
Sulphite	1	*pr*	*r*	$Ce^{2}S^{3}$	35							
	2	*pr*	*or*	Ce S	15·5							
Sulphate	1	*pr*	*r*	Ce S O^{2}	23·5	2·5		*w*		5	6·5	3·375†
	2	*pr*	*y*	$Ce^{2}S$ O^{2}	39				*ef*	5	13	2·25†
	3	*nd*	*y*	Ce $S^{2}O^{5}$	31·5					7·5	7	5 625†
	4	*pr*	*w*	Ce S O	19·5					5	14†	
Potash Ditto	1	*pr*	*w*	K Ce S O^{2}	33·5			*w*		11	11·5†	
	2	*pr*	*y*	K $Ce^{2}S$ O	45			*w*		11	14·5†	
Nitrate	1	*cr*	*r*	Ce Z O^{3}	27			*w*				
	2	*ld*	*y*	$Ce^{2}Z$ O^{5}	38·5							
	3	*ld*	*r*	Ce $Z^{2}O^{5}$	30·5							
Chloride	1	*pm*	*w*	Ce Cl	20·5			*w*	*d*			
	2	*gm*	*y*	$Ce^{2}Cl$	32							
Chloro hydrargyrate		*cb*	*w*	Ce Mr Cl O	45·5							
Fluoride	1	*pr*	*w*	$Ce^{2}F^{3}$	36·5			*w*				
	2	*pr*	*y*	Ce F^{2}	20·5			*w*				
Phosphite		*pr*	*gy*	$Ce^{2}P^{3}$	35							

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											Acid.	Base.	Water.	
Phosphate	1	*pr*	*bn*	Ce P O^2	23·5						4·5	9·75†		
	2	*ct*	*bn*	Ce P^2O^2	27·5						4·5	10·5†		
Selenite	1	*pr*	*y*	Ce^2Se^3	33									
	2	*pr*	*or*	Ce Se^2	31·5									
	3	*pr*	*w*	Ce Se	21·5				*w*					
	4	*pr*	*w*	Ce^4Se^7	116									
Arsenite		*pr*	*w*	Ce^2As^3	51·5									
Sulpho Ditto		*pr*	*or*	Ce As S^4	33									
Hypo Ditto Ditto		*pr*	*r*	Ce As S^5	37									
Arseniate	1	*pr*	*w*	Ce As O^2	29									
	2	*pr*	*w*	Ce As^2O	34·5									
Sulpho Ditto	1	*pr*	*y*	Ce As S O	29				*w*					
	2	*pr*	*y*	Ce As S^2O	33				*w*					
	3	*cr*	*w*	Ce As^2S O	38·5				*w*					
Chromate	1	*pr*	*y*	Ce Cr O^2	26·5									
	2	*pm*	*r*	Ce Cr^2O^2	33·5				*w*					
Molybdate		*pr*	*w*	Ce Mo O^2	31·5				*ac*					
Sulpho Ditto	1	*pr*	*bn*	Ce Mo S O^2	35 5									
	2	*pr*	*bn*	Ce Mo S^2O^2	39·5									
Ditto tungstate		*pr*	*y*	Ce W S O^2	31·5				*w*	*d*				
Carburet		*m*	*bk*	Ce C	14·5									
Carbonate		*gr*	*bk*	Ce^2C O^3	38						2·75	6·5	1·125†	
Potash Ditto	1	*gr*	*y*	K Ce C O^3	36·5									
	2	*pr*	*w*	K Ce C^2O	39·5									
Ferro cyanodide		*pr*	*w*	Ce Z C Fe	25				*w*					
Sulpho tellurate		*sd*	*bn*	Ce Te S^2O	31·5									
Oxalate	1	*pr*	*w*	Ce C O^2	22·5						4·5	6·5†		
	2	*pr*	*r*	Ce C^2O^4	33·5						6·75	7	·5625†	
Potash Ditto		*pr*	*w*	K Ce C O^2	32·5									
Acetate		*cr*	*w*	Ce H C O^3	26·75				*w*					
Tartrate		*fk*	*w*	Ce $H^2C^4O^5$	44									
Citrate		*pr*	*w*	Ce $H^6C^4O^6$	49									
Succinate		*pr*	*w*	Ce $H^2C^4O^3$	36									
Benzoate		*pr*	*w*	Ce $H^5C^{14}O^3$	66·75									

COBALT		*m*	*gy*	Co	7	8·73		130					
Oxide	1	*pr*	*bl*	Co^2O	18								
	2	*pr*	*bk*	Co^4O^3	40	5·322							
Hydrate		*pr*	*m*	Co H O^2	15·25								
(Acid)	3	*cr*	*br*	Co O	11								
	4	*cr*	*br*	Co O^2	15								
Sulphite	1	*pr*	*bk*	Co S	11						26	30	44U
	2	*pr*	*w*	Co^2S^3	26					*ef*			
	3	*pr*	*bk*	Co S^2	15								
	4	*pr*	*bk*	Co^4S	32								
	5	*pr*	*bl*	Co^4S^3	40								
Sulphate	1	*pm*	*gn*	Co S O^2	19						10	4·25	3·375†
	2	*pm*	*r*	Co^2S O^2	26						9	4·25	6·75†
	3	*pr*	*r*	Co S^2O^3	27						5	4·25	7 875†
	4	*cr*	*r*	Co S O	15						20	4·25	1·125
Potash Ditto		*pr*	*w*	H Co S O^2	29						9·25	11	6·75
Ammonia Ditto		*cr*	*r*	Am^2Co S O	28·5					*d*	9·25	7·125	9·00
Nitrate		*pm*	*r*	Co Z O^3	22·5				*w*	*d*	6·75	4·25	6·75
Ammonia Ditto		*cr*	*r*	Am^2Co Z O^3	31·5						7·125	9·25	7·875
Chloride		*cr*	*bl*	Co Cl	16				*w*	*d*	1	1	5
Ammonia Ditto		*pr*	*y*	Am^2Co Cl	25								
Chloro aurate		*pr*	*y*	Co Au Cl	32·5								
Ditto platinate		*pr*	*bn*	Co Pt Cl	28·25				*w*				
Ditto hydrargyrate		*pr*	*w*	Co Mr Cl	41						1	1	4
Bromide		*pr*	*r*	Co^2Bm^3	74								
Iodide		*pr*	*r*	Co^2I^3	110								
Fluoride		*pr*	*r*	Co^2F^3	27·5				*w*				
Phosphite		*pr*	*r*	Co^2P^3	26								
Phosphate		*pr*	*r*	Co P O^2	19						4·5	4·25	2·25†
Selenite		*pr*	*gy*	Co^2Se^3	44								
Arsenite		*m*	*gy*	Co^2As^3	42·5								
Sulpho Ditto		*pr*	*bk*	Co As S^4	32·5								
Hypo Ditto Ditto		*pr*	*bk*	Co As S^5	36·5								
Arseniate		*pm*	*bl*	Co As O^2	24·5						7·25	4·25	4·5†
Sulpho Ditto		*pr*	*y*	Co As S^2O	28·5								
Chromate		*pr*	*bn*	Co Cr O^2	22								
Molybdate		*pr*	*y*	Co Mo O^2	27								
Sulpho Ditto		*pr*	*bn*	Co Mo S O	27				*w*				
Ditto tungstate		*pr*	*bk*	Co W S O	23				*w*				
Borate		*pr*	*r*	Co B O	12				*w*				

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											Acid.	Base.	Water.	
Carbonate		*pr*	*vi*	$Co^2C\ O^3$	29						2·75	4·25	1·125†	
Bisulpho Ditto		*fk*	*bk*	Co C S^2O	22									
Cyanodide		*pr*	*w*	Co C Z	13·5				*w a*					
Sulpho Ditto		*pm*	*bl*	Co C Z S O	17·5				*w*					
Ferro Ditto		*pr*	*r*	Co C Z Fe	20·5		680		*ac*					
Fulminate		*cr*	*y*	Co H C Z O	17·25									
Antimonite		*pr*	*li*	Co Sb	18									
Antimoniate		*gr*	*r*	Co Sb O^2	26				*w*		52	14	33·3†	
Sulpho tellurate		*pr*	*bk*	Co Te S^2O	27									
Silicate		*sd*	*bn*	Co Si O	13									
Fluo Ditto		*pr*	*r*	Co Si F O	17·5				*w*					
Oxalate		*pr*	*r*	Co C O^2	18						4·5	4·25	2·5†	
Ammonia Ditto		*pr*	*r*	Am Co C O^2	22·5									
Acetate		*ld*	*r*	Co H C O^3	22·25				*w*					
Lactate		*ct*	*r*	Co H C^3O^4	32·25				*w*					
Formate		*cr*	*r*	Co H C O^3	22·25									
Tartrate		*cr*	*r*	Co $H^2C^4O^5$	39·5				*w*		8·25	4·25	2·25†	
Potash Ditto		*cr*	*w*	K Co $H^2C^4O^5$	49·5									
Succinate		*pr*	*r*	Co $H^2C^4O^3$	31·5									
Benzoate		*cr*	*r*	Co $H^5C^{14}O^3$	62·25									
Oleate		*sd*	*gn*	Co $H^3C^{14}O$	53·75									
Pinate		*pr*	*bl*	Co $H^{12}C^{11}O^2$	51									
NICKEL		*sd*	*w*	Ni	7	8·380								
Oxide	1	*pr*	*gy*	Ni^2O^3	26									
	2	*pr*	*bk*	Ni O	11									
Hydrate		*pr*	—	Ni H O	11·25									
	3	*pr*	*gn*	Ni^4O^3	40									
	4	*pr*	*bl*	Ni O^2	15									
Sulphite	1	*pr*	*br*	Ni S	11									
	2	*pr*	*y*	Ni^2S	18									

Sulphate	1	*pm*	*w*	Ni S O^2	19			*w*		5	4·25	7·875†
	2	*pr*	*gn*	Ni S^2O	19			*w*		29	25·35	45·65U
Potash Ditto		*pm*	*gn*	K Ni S O^2	29			*w*		9·45	11	6·75†
Ammonia Ditto		*pm*	*gn*	Am^3Ni S O^2	32·5			*w*		9·250	7·125	7·875†
Ferro Ditto		*pl*	*gn*	Ni Fe S O^2	26			*w*	*ef*			
Nitrate	1	*cr*	*w*	Ni Z O^3	22·5			*w a*	*d*	6·75	4·25	56·25†
	2	*pr*	*w*	Ni Z^2O^6	38					6·75	46·75	
Ammonia Ditto		*cr*	*gn*	Am Ni Z O^3	27			*w*				
Chloride	1	*cr*	*sl*	Ni^2Cl	23			*w*	*d*	11	34	55
	2	*cr*	*gn*	Ni Cl	16			*w a*	*d*	1	1	6†
Ammonia Ditto		*cr*	*w*	Am^3Ni Cl	29·5			*w*				
Chloro Aurate		*pm*	*y*	Ni Au Cl	32·5			*w*				
Ditto platinate		*pm*	*gn*	Ni Pt Cl	28·25			*w*		1	1	6†
Ditto palladiate		*pm*	*gy*	Ni Pd Cl	22·5			*w*				
Ditto hydrargyrate		*cr*	*gn*	Ni Mr Cl	41							
Bromide		*pr*	*gy*	Ni^2Bm^3	74							
Iodide		*pr*	*br*	Ni^2I^3	110							
Fluoride		*pr*	*gn*	Ni^2F^3	27·5			*w*				
Phosphite		*pr*	*w*	Ni^2P^3	26			*w*				
Phosphate		*pr*	*w*	Ni P O^2	19					4·5	4·25	3·375†
Ammonia Ditto		*fk*	*gn*	Am Ni P O^2	23·5							
Magnesia Ditto		*pr*	*w*	Ni Mg P O^2	22							
Selenite	1	*pr*	*gn*	Ni^2Se^3	44							
	2	*pm*	*gn*	Ni Se^2	27							
Arsenite	1	*pr*	*r*	Ni^2As^3	42·5							
	2	*pr*	*w*	Ni As^2	26							
Sulpho Ditto		*pr*	*bk*	Ni As S^4	32·5							
Hypo Ditto Ditto		*pr*	*br*	Ni As S^5	36·5							
Arseniate	1	*pr*	*gn*	Ni As^2O^3	38			*w*		7·25	4·25	6·75†
	2	*pr*	*gn*	$Ni^3As^2O^4$	54					14·5	4·25	11·28†
	3	*cr*	*gn*	Ni^4As O^7	94					7·25	8·5	5·625†
Sulpho Ditto		*pr*	*br*	Ni As S O	24·5							
Chromate		*pr*	*r*	Ni Cr O^2	22					6·5	4·25	4·5†
Molybdate		*pr*	*w*	Ni Mo O^2	27							
Sulpho Ditto		*pr*	*bn*	Ni Mo S O^2	31			*w*				
Ditto tungstate		*pr*	*bk*	Ni W S O^2	27			*w*				
Borate		*pr*	*gn*	Ni B O	12							
Carburet		*pr*	*br*	Ni C^2	13							
Carbonate	1	*pr*	*br*	Ni^2C O^3	29					1	1	3†
	2	*pr*	*br*	Ni C^2O	17					1	1·5	3·5†

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											Acid.	Base.	Water.	
Carbonate	3	*pr*	*br*	Ni C^2O^5	33						1	2	7†	
Bisulpho Ditto		*pr*	*bk*	Ni C S^2O^3	30									
Potash Ditto		*pr*	*br*	K Ni C S O^3	36									
Cyanodide		*pr*	*gy*	Ni C Z	13·5									
Sulpho Ditto		*pr*	*gy*	Ni C Z S	16·5				*w*					
Ferro Ditto		*fk*	*gn*	Ni C Z Fe	20·5				*w*					
Fulminate		*cr*	*bk*	Ni H C Z O	19·75				*w*					
Antimonite		*pr*	*gy*	Ni Sb^2	29									
Antimoniate		*pr*	*gy*	Ni Sb O^2	27									
Sulpho tellurate		*pr*	*bk*	Ni Te S^2O	27									
Fluo silicate		*pr*	*gn*	Ni Si^2F^3O	28·5				*w*					
Oxalate		*pr*	*w*	Ni C O^2	18				*w*		4·5	4·25	4·5†	
Ammonia Ditto		*pm*	*gn*	Am Ni C O^2	22·25									
Acetate		*pm*	*gn*	Ni H C O^3	22·25				*w*		6·75	4·25	5·625†	
Lactate		*cr*	*gn*	Ni H C^3O^4	32·25									
Formate		*nd*	*gn*	Ni H C^2O^3	25·25									
Tartrate		*pr*	*gn*	Ni $H^2C^4O^5$	39·5				*w*		9·25	4·25†		
Potash Ditto		*pr*	*gn*	Ni $H^2C^4O^5$	49·5				*w*					
Citrate		*fk*	*gn*	Ni $H^3C^2O^3$	25·75				*ac*					
Pyromucate		*pr*	*gn*	Ni $H^2C^9O^6$	58·5									
Succinate		*pr*	*gn*	Ni $H^2C^4O^3$	31·5									
Benzoate		*pl*	*gn*	Ni $H^5C^{14}O^3$	62·25				*w a*					
Oleate		*pr*	*gn*	Ni $H^3C^{14}O$	53·75									
Pinate		*m*	*gn*	Ni $H^{12}C^{11}O^2$	51									
Aspartate		*m*	*gn*	Ni H C O										
Sulpho naphthalate		*cr*	*gn*	Ni Z^6C^9S O^4	75·5									
IRON		*sd*	*gy*	Fe	7	7·843		158						
Oxide	1	*pr*	*bl*	Fe^2O	18									
	2	*pr*	*r*	Fe^3O^2	29									
	3	*pr*	*r*	Fe^4O^3	40									
	4	*pr*	*br*	Fe O	11									

Sulphated Ditto.....	1	*ld*	*r*	Fe S O^2	19					7·5	5†	
	2	*pr*	*r*	Fe S^2O^2	23					5	20	6·75†
Nitrated.....	1	*ld*	*bn*	Fe Z O^3	22·5				*d*	10·125	5	9†
	2	*pr*	*bn*	Fe Z^2O^5	26					6·75	40	2·25†
Phosphated.....	1	*pr*	*w*	Fe P O^2	19		*w ac*			4·5	5†	
	2	*ld*	*r*	Fe P^2O^2	23					4·5	10	3·375†
Selenited	1	*pr*	*w*	Fe Se O^2	25							
	2	*pr*	*gn*	Fe Se^2O^5	39							
	3	*pr*	*gn*	Fe^2Se O^3	36							
Arseniated.....	1	*pr*	*w*	Fe As O^2	24·5					10·875	5	3·375†
	2	*pr*	*or*	Fe As^2O^2	34		*ac*					
	3	*pr*	*bn*	Fe^2As O^3	35·5					7·25	80	13·5†
Chromated.....	1	*pr*	*bn*	Fe Cr O^3	27					6·5	25	10·125†
	2	*pr*	*or*	Fe^2Cr O^4	38		*w*			6·5	10	5·625†
Molybdated.....		*pr*	*bn*	Fe Mo O^3	31							
Borated.....		*pr*	*bn*	Fe B O^2	16							
Antimoniated		*pr*	*y*	Fe Sb O^2	26							
Silicated.....		*pr*	*bn*	Fe Si O^2	17							
Oxalated.....		*pr*	*y*	Fe C O^2	22		*ac*					
Acetated		*gm*	*y*	Fe C O^4	26							
Lactated		*pr*	*bn*	Fe H C^3O^5	36·5		*w*					
Formated		*nd*	*y*	Fe H C^2O^4	29·5		*w a*					
Mellated.....		*pr*	*y*	Fe H C^6O^4	41·25		*ac*					
Tartrated.....		*gm*	*y*	Fe $H^2C^4O^6$	43·5		*w*					
Pyro Ditto.....		*pr*	*y*	Fe $H^3C^4O^5$	39·75							
Vinated.....		*pr*	*y*	Fe H C^2O^3	33·25							
Citrated.....		*pr*	*bn*	Fe $H^3C^2O^4$	29·75		*w*					
Malated		*gm*	*y*	Fe H C^4O^5	39·25							
Pyromucated.....		*pr*	*y*	Fe $H^{14}C^9O^5$	57·5					6·25	5	1·6875†
Succinated.....	1	*fk*	*r*	Fe $H^2C^4O^4$	35·5							
	2	*pr*	*y*	Fe $H^{14}C^4O^{10}$	62·5							
	3	*pr*	*r*	$Fe^2H^{14}C^4O^{10}$	68·5							
Benzoated.....	1	*pr*	*r*	Fe $H^5C^{14}O^4$	66·25					15	5†	
	2	*pr*	*r*	Fe $H^{10}C^5O^6$	44·5							
	3	*pr*	*r*	$Fe^2H^{10}C^5O^6$	50·5							
Gallated.....		*pr*	*bl*	Fe $H^7C^3O^5$	37·75							
Meconated.....		*pr*	*r*	Fe $H^9C^9O^5$	56·25							
Bolated		*gm*	*r*	Fe H C O								
Camphorated.....		*pr*	*bn*	Fe $H^3C^2O^2$	21·5							
Suberated.....		*pr*	*bn*	Fe $H^4C^{12}O^3$	23							

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											Acid.	Base.	Water.	
Pinated		*sd*	*bn*	Fe $H^{12}C^{11}O^{2}$	51									
Silvated		*pr*	*bn*	Fe H C O										
Oxide	5	*pr*	*bk*	$Fe^{2}O^{3}$	26									
Hydrate		*pr*	*bn*	$Fe^{2}H$ O^{4}	30·25									
Sulphite	1	*m*	*gy*	$Fe^{2}S$	18									
	2	*pr*	*gy*	Fe S	11									
	3	*pr*	*gy*	Fe S^{2}	15	4·5								
	4	*pr*	*y*	$Fe^{4}S$	32									
	5	*pr*	*gy*	$Fe^{7}S^{8}$	81									
	6	*pr*	*y*	$Fe^{2}S^{3}$	26									
Hypo Ditto		*pr*	*gn*	Fe S^{5}	27									
Sulphate	1	*pm*	*gn*	Fe S O^{2}	19	1·754			*w*		28·9	25·7	45·4	
	2	*m*	*w*	$Fe^{2}S$ O^{2}	26									
	3	*pr*	*or*	Fe $S^{3}O^{2}$	27						20	80		
	4	*cr*	*gn*	Fe $S^{2}O^{2}$	23	1·980			*w*		31·6	16·8	52·6	
	5	*m*	*gn*	Fe S O	15				*w*	*d*	60	40		
	6	*m*	*r*	Fe $S^{2}O$	19				*w*	*d*	7·5	5		
Hypo Ditto		*pr*	*r*	Fe $S^{2}O^{5}$	35				*w*	*ef*	9	4·5	5·625	
Potash Ditto	1	*cr*	*gn*	K Fe S O^{2}	29				*w*	*ef*	11	9·5	5·625	
	2	*cr*	*gy*	K Fe $S^{2}O^{2}$	33						11	10	2·25	
	3	*cr*	*w*	K Fe $S^{2}O$	29						11	25	22·125	
Ammonia Ditto	1	*cr*	*y*	Am Fe S O^{2}	23·5						10	7·125	3·375	
	2	*cr*	*w*	Am Fe S O	19·5						25	7·125	28·125	
Nitrate	1	*l*	*gn*	$Fe^{2}Z$ O^{3}	31·5					*d*				
	2	*pm*	*gn*	Fe $Z^{2}O^{3}$	26					*d*	6·75	40	2·25	
	3	*pm*	*gn*	Fe Z O^{3}	22·5				*w*	*d*				
	4	*pr*	*gn*	$Fe^{2}Z^{2}O^{3}$	35				*w*	*d*	10·125	5	9	
Chloride	1	*pl*	*gy*	$Fe^{2}Cl^{3}$	41				*w a*		1	1	4	
	2	*m*	*br*	Fe Cl	16				*w a*					
	3	*m*	*or*	Fe Cl^{2}	25				*w a*	*d*				
Chloro platinate		*cr*	*bn*	Fe Pt Cl O	28									
Ditto hydrargyrate		*pm*	*y*	Fe Mr Cl O	32·5						1	1	6	
Chlorate		*pr*	*r*	Fe Cl	45									

Bromide	1	*tb*	*y*	Fe^2Bm^3	74				*w*	*d*	.1	1	6
	2	*ld*	*bn*	Fe Bm^2	47				*w*	*d*			
Iodide	1	*pr*	*bn*	Fe^2I^3	110								
	2	*pr*	*br*	Fe I^2	71								
Iodo hydrargyrate		*pm*	*y*	Fe Mr I^2	96				*w*	*d*			
Fluoride	1	*pr*	*w*	Fe^2F^3	27·5				*w*				
	2	*pr*	*r*	Fe^4F^3	41·5								
	3	*pr*	*gy*	Fe^4F	32·5								
	4	*pr*	*r*	Fe F	11·5								
Phosphite	1	*pr*	*w*	Fe^2P^3	26								
	2	*pr*	*w*	Fe P^2	15								
	3	*pr*	*w*	Fe^3P^2	29								
Phosphate	1	*pm*	*bl*	Fe P O^3	23	2·6					21	45	34
	2	*pr*	*bl*	Fe^2P O^3	30				*w*				
	3	*pr*	*w*	Fe P^2O^3	27				*w*				
	4	*pr*	*or*	Fe P^3O^3	31								
	5	*pr*	*br*	Fe P O	15				*w*		5·25	5	9
	6	*pr*	*w*	Fe P^2O	19				*w*		3·5	15	3·375
Ammonia Ditto	1	*pr*	*w*	Am^2Fe P O	24								
	2	*pr*	*w*	Am Fe P O	20·5								
Selenite	1	*pr*	*gy*	Fe^2Se^3	44								
	2	*pr*	*gy*	Fe Se^2	27								
	3	*pr*	*gy*	Fe^3Se^2	41								
	4	*pr*	*y*	Fe Se	17								
	5	*pr*	*y*	Fe^4Se	38								
Arsenite		*pr*	*w*	Fe^2As^3	42·5								
Sulpho Ditto	1	*pr*	*br*	Fe As S^4	32·5								
	2	*pr*	*gn*	Fe^2As S^4	39·5								
Hypo Ditto Ditto		*pr*	*gn*	Fe As S^5	36·5								
Arseniate	1	*pr*	*w*	Fe As^2O^5	38	3·0					36	52	12
	2	*pr*	*y*	Fe^2As O^5	35·5								
	3	*pr*	*w*	Fe As^2O	30								
	4	*pr*	*or*	Fe As O	20·5						42·4	37·2	20·4
	5	*pr*	*y*	Fe^2As^2O	37								
	6	*pr*	*or*	$Fe^2As^3O^5$	62·5								
	7	*pr*	*or*	Fe As^3O^5	55·5								
Sulpho Ditto	1	*pr*	*bk*	Fe As S^2O	28·5								
	2	*fk*	*gy*	Fe As^2S^2O	38								
Chromide	1	*sd*	*br*	Fe^2Cr^3	35								
	2	*sd*	*br*	Fe^3Cr^4	49								

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											Acid.	Base.	Water.	
Chromate	1	*pr*	*gn*	Fe Cr O^2	22									
	2	*pr*	*gn*	Fe Cr^2O	25									
	3	*pr*	*gn*	Fe^2Cr O	25									
Molybdide		*sd*	*gy*	Fe^2Mo^3	50									
Molybdate		*pr*	*br*	Fe Mo O^2	27									
Sulpho Ditto	1	*pr*	*r*	Fe Mo S^4O^2	43				*w*					
	2	*pr*	*bk*	Fe $Mo^2S^4O^2$	55				*w*					
Hyper Ditto Ditto		*pr*	*r*	Fe Mo S^5O^2	47				*w*					
Tungstide		*pr*	*bn*	Fe^2W^3	38									
Tungstate		*pr*	*bk*	Fe W O^2	23									
Sulpho Ditto	1	*pr*	*y*	Fe W S O^2	27				*w*	*d*				
	2	*pr*	*bn*	Fe W S^2O^2	31				*w*	*d*				
Borate	1	*pr*	*y*	Fe B O	12									
	2	*pr*	*y*	Fe B^2O	13									
Fluo Ditto		*pr*	*bn*	Fe B F O	16·5									
Carburet	1	*pr*	*r*	Fe^2C	17									
	2	*pr*	*bn*	Fe C^2	15									
	3	*pr*	*bn*	Fe C	11									
	4	*pr*	*bn*	Fe^2C^5	29									
Carbonate	1	*pr*	*bk*	Fe^2C O^3	29						24	76		
	2	*pr*	*br*	Fe C^2O^3	25	3·33					36	59·5	2	
Sulpho Ditto	1	*pr*	*gy*	Fe C S^2O	22									
	2	*pr*	*r*	$Fe^2C^2S^2O^2$	36									
Potash Ditto		*ld*	*r*	K Fe C S O^2	32									
Ammonia Ditto		*ld*	*br*	Am Fe C S O^2	26·5									
Cyanodide	1	*m*	*y*	Fe C Z	13·5				*a*					
	2	*pr*	*y*	Fe^2C Z	20·5									
Ferro Ditto	1	*pr*	*bl*	Fe C Z Fe	20·5		275				1	1	1·5	
	2	*pr*	*gn*	Fe^2C Z Fe	27·5						1	2	2	
Cyanate		*ld*	*w*	Fe H C Z O^2	21·75				*w*					
Hydro sulpho Ditto	1	*pr*	*gn*	Fe H C Z S^2O^2	29·75									
	2	*pr*	*r*	Fe H C Z S O^2	25·75									
Fulminate		*pr*	*r*	Fe H C Z O	17·75									
Antimonite		*sd*	*w*	Fe Sb	18									

Antimoniate	1	*pr*	*w*	Fe Sb O^3	30							
	2	*pr*	*y*	Fe^2Sb O^3	37							
Sulpho Ditto		*pr*	*y*	Fe Sb S O^3	34							
Ditto tellurate	1	*sd*	*bk*	Fe Te S O	23				*w*			
	2	*sd*	*gy*	Fe Te S^2O	27				*w*			
Tantalate		*pr*	*br*	Fe Ta O	26							
Titaniate	1	*sd*	*bn*	Fe Ti O^3	22					5·25	4·5†	
	2	*sd*	*bn*	Fe Ti^4O^5	39					21	4·5†	
	3	*sd*	*gy*	Fe^4Ti O^5	51					5·25	18†	
	4	*sd*	*gn*	Fe^8Ti O^9	95					5·25	36†	
	5	*sd*	*bn*	Fe^2Ti^2O	24					50·5	4·5†	
Fluo Ditto		*ld*	*y*	Fe Ti^2F^3O	30·5				*w a*			
Silicate	1	*sd*	*bn*	Fe^2H Si O^5	28·25					2	9	1·125†
	2	*sd*	*bn*	Fe^2H^2Si O^4	32·5					2	9	2·25†
	3	*sd*	*bk*	Fe H Si O^4	25·25					2	4·5	1·125†
	4	*sd*	*bk*	Fe H Si O^2	17·25					2	4·5	1·125†
	5	*sd*	*bn*	Fe H Si^3O^2	21·25					6	4·5	1·125†
	6	*sd*	*bk*	Fe $H^2Si^3O^3$	25·5					6	4·5	2·25
	7	*sd*	*bn*	$Fe^2H^5Si^6O^9$	63·5					6	4·5	2·8125†
Fluo Ditto	1	*pm*	*gn*	Fe Si^2F^3O	28·5				*w*			
	2	*m*	*r*	$Fe^2Si^4F^3O$	39·5							
Oxalate	1	*pm*	*w*	Fe C O^2	18				*w*	55	45	
	2	*pr*	*y*	Fe C^2O^3	25				*w*	4·5	4·5	2·25
Potash Ditto		*cr*	*gn*	K Fe C O^2	28				*w*			
Ammonia Ditto		*pr*	*y*	Am Fe C O	22·5				*w*			
Acetate	1	*pm*	*gn*	Fe H C O^3	22·25	1·368			*w*	*ef*	6·28	4·5	3·375†
	2	*gn*	*w*	Fe H C O	14·25				*w*			
Lactate	1	*pr*	*bn*	Fe H C^3O^4	32·25				*w*			
	2	*nd*	*w*	Fe $H^6C^5O^8$	55·5							
Formate	1	*ld*	*w*	Fe H C^2O^3	25·25							
	2	*ld*	*w*	Fe^2H C^2O^3	32·25							
Mellate		*pr*	*w*	Fe H C^4O^3	31·25							
Tartrate	1	*cr*	*w*	Fe $H^2C^4O^5$	39·5						8·25	4·5	2·25†
	2	*gm*	*r*	$Fe^2H^2C^4O^5$	49·5				*w a*			
Potash Ditto	1	*nd*	*w*	K Fe $H^2C^4O^5$	49·5							
	2	*pr*	*y*	K $Fe^2H^2C^4O^5$	56·5							
Pyro Ditto		*pr*	*bn*	K Fe $H^3C^4O^4$	35·75							
Vinate		*nd*	*w*	Fe H C^2O^4	29·25				*w*			
		nd	*w*	Fe^2H C^2O^4	36·25							
Sulpho Ditto	1	*cr*	*bn*	Fe H C^2S O^4	33·25					*ef*			
	2											

Name of the Element, and its Combinations.		Form.	Colour.	Symbols of the Components, and their Quantities.	Atom. Wt. and Numbers, Equivalent Hyd. = 25.	Specific Gravity Water = 1·000	Fusibility, Fahrenheit.	Fusibility, Wedgwood.	Solubility.	Atmospheric Action.	Theoretic Composition.			Trivial Name.
											Acid.	Base.	Water.	
Ammonia Ditto.....		*gr*	*br*	Am Fe H C^2O^4	37·75									
Citrate.....	1	*pr*	*bn*	Fe $H^3C^2O^2$	25·75				*w*					
	2	*pr*	*bn*	Fe $H^3C^3O^3$	28·75									
	3	*m*	*w*	$Fe^2H^3C^2O^3$	32·75				*w*	*d*				
Malate.....	1	*m*	*w*	Fe H C^4O^4	35·25									
	2	*ld*	*br*	Fe^2H C^4O^4	42·25									
Mucate.....		*m*	*br*	Fe $H^5C^6O^8$	58·25									
Pyro Ditto.....	1	*cr*	*bn*	$Fe^2H^{14}C^9O^4$	88·5				*w*					
	2	*cr*	*bn*	Fe $H^2C^5O^4$	38·5				*w*					
Succinate.....	1	*cr*	*w*	Fe $H^2C^4O^3$	31·5									
	2	*nd*	*w*	$Fe^2H^2C^4O^3$	38·5									
	3	*pr*	*br*	Fe $H^{14}C^6O^9$	64·5						61·5	38·5		
	4	*pr*	*br*	$Fe^2H^{14}C^6O^9$	71·5									
Benzoate.....	1	*pr*	*y*	Fe H^2C^3O	20·5				*w a*	*ef*				
	2	*pr*	*w*	$Fe^2H^2C^3O$	27·5									
	3	*cr*	*y*	Fe $H^{10}C^{15}O^5$	74·5									
	4	*cr*	*bn*	$Fe^2H^{10}C^{15}O^5$	81·5									
Gallate.....	1	*ld*	*gy*	Fe $H^7C^3O^4$	33·75				*w a*	*ef*				
	2	*pr*	*bk*	Fe $H^{14}C^6O^8$	60·5									
Meconate.....		*pr*	*bn*	Fe $H^9C^9O^4$	52·25									
Boletate.....	1	*ld*	*y*	Fe H C O										
	2	*pr*	*r*	Fe^2H C O										
Camphorate.....		*pr*	*y*	Fe H^3C^2O	17·75									
Suberate.....	1	*pr*	*w*	Fe H^4C O^2	19									
	2	*cr*	*y*	Fe^2H^4C O^2	26									
Pinate.....	1	*pr*	*bn*	Fe $H^{12}C^{11}O^2$	51									
	2	*cr*	*w*	$Fe^2H^{12}C^{11}O^2$	58									
Silvate.....	1	*pr*	*bn*	Fe H C O										
	2	*cr*	*bn*	Fe^2H C O										
Pyrurate.....		*cr*	*y*	Fe $H^2C^3O^2$	24·5									
Sulpho naphthalate...		*cr*	*w*	Fe $H^6C^9S^4O$	55·5									

CADMIUM		*sd*	*w*	Cd	14	8·659	440						
Oxide	1	*pr*	*y*	Cd^2O	32								
	2	*pr*	*br*	Cd O	18								
Hydrate		*pr*	*w*	Cd H O	18·25								
Sulphite		*pr*	*or*	Cd S	18								
Sulphate	1	*pm*	*w*	Cd S O^2	26					*ef*	28·52	45·95	25·52U
	2	*pr*	*w*	Cd S^2O	26					*ef*	5	8	4·5†
Hypo Ditto		*pr*	*w*	Cd^2S^3O	44								
Potash Ditto		*pr*	*w*	K Cd S O^2	36				*w*				
Ammonia Ditto		*pr*	*w*	Am^3Cd S O^2	39·5				*a*		6·75	8	4·5
Nitrate		*cr*	*w*	Cd Z O^3	29·5				*w*	*d*	35·78	42·15	22·06U
Chloride		*pl*	*w*	Cd Cl	23				*w*	*ef*	38·6	61·4U	
Chloro aurate		*pm*	*or*	Cd Au Cl	39·5								
Ditto platinate		*pm*	*bn*	Cd Pt Cl	35·25						1	1	6
Ditto palladiate		*nd*	*bn*	Cd Pd Cl	29·5								
Bromide ?				Cd^2Bm^3									
Iodide		*pr*	*w*	Cd^2I^3	124								
Fluoride		*ct*	*w*	Cd^2F^3	41·5				*w*				
Phosphite		*pr*	*gy*	Cd^2P^3	40						30·71	69·29U	
Phosphate		*pr*	*w*	Cd P O^3	30						4·5	10	1·6875†
Arsenite		*pr*	*w*	Cd^2As^3	56·5								
Sulpho Ditto		*pr*	*cr*	Cd As S^4	39·5								
Hypo Ditto Ditto		*pr*	*w*	Cd As S^5	43·5								
Arseniate		*pr*	*w*	Cd As O^3	35·5						7·25	8	1·6825†
Sulpho Ditto		*pr*	*or*	Cd As S^2O^5	51·5								
Chromate		*pr*	*y*	Cd Cr O^2	29				*w*				
Molybdate		*pr*	*gy*	Cd Mo O^2	30				*w*		6·5	8	5·625†
Sulpho Ditto		*pr*	*bn*	Cd Mo S^4O	44				*w*				
Hyper Ditto Ditto		*pr*	*bn*	Cd Mo S^5O	50				*w*				
Sulpho tungstate		*pr*	*y*	Cd W S O^2	34				*w*				
Borate		*pr*	*w*	Cd B O^3	27						27·88	72·12U	
Carbonate		*pr*	*w*	Cd^2C O^3	45						2·75	8†	
Bisulpho Ditto		*pr*	*y*	Cd C S^2O	29				*w*		25·45	74·55U	
Fulminate		*cr*	*y*	Cd H C Z O	24·75								
Sulpho tellurate		*sd*	*bn*	Cd Te S O	30								
Fluo silicate		*pm*	*w*	Cd Si^2F^3	31·5				*w*				
Oxalate	1	*pr*	*w*	Cd C O^2	25						4·5	8	3·375†
	2	*pr*	*r*	Cd C^2O^4	36								
Acetate		*pm*	*w*	Cd H C O^3	29·25				*w*		7	8	2·25†
Formate		*cr*	*w*	Cd H C^2O^3	32·25						4·625	8	2·25†

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											Acid.	Base.	Water.	
Tartrate		*nd*	*w*	Cd $H^2C^4O^5$	46·5						8·25	8	2·25†	
Succinate		*pr*	*w*	Cd $H^2C^4O^3$	38·5									
Citrate		*pr*	*w*	Cd $H^6C^4O^6$	51·5						9·25	8	2·25†	
ZINC		*sd*	*w*	Zn	8	7·55	680							
Oxide	1	*pr*	*w*	Zn^2O	20									
	2	*pr*	*gy*	Zn O	12									
	3	*pr*	*gy*	Zn O^2	16									
Hydrate		*pr*	*w*	Zn H O	12·25									
Sulphite	1	*cr*	*w*	Zn^2S	20				*w a*		3	5·25		
	2	*pm*	*w*	Zn S^2	16				*w a*					
Sulphate	1	*pr*	*w*	Zn S O^2	20				*w*		5	5·25	7·875	
	2	*ct*	*w*	Zn S^2O	20				*w*		5	5·25	3·375	
	3	*pr*	*w*	Zn^3S O^2	36				*w*		5	15·75		
Hypo Ditto		*pr*	*w*	Zn^2S^3O	32						9	5·25	6·25†	
Potash Ditto		*pr*	*w*	K Zn S O	26						10·25	11	7·875	
Ammonia Ditto		*pm*	*w*	Am Zn S O	20·5				*w*		10·25	7·125	7·875	
Ferro Ditto		*pr*	*gn*	Fe Zn S O	23				*w*		9·5	10·25	15·75	
Nickel Ditto		*pr*	*w*	Ni Zn S O	23				*w*	*ef*				
Cobalt Ditto		*pm*	*bl*	Co Zn S O	23				*w*	*ef*				
Vegeto Ditto		*ld*	—	Zn H C S O	19·25				*w*					
Nitrate	1	*pm*	*w*	Zn Z O^3	23·5	2·085			*w*	*d*	6·75	5·25	6·75†	
	2	*cr*	*w*	Zn^2Z O^3	31·5	2·096			*w*	*d*	6·75	42	2·25†	
Chloride		*m*	*w*	Zn Cl	17	1·577			*w*	*d*				
Chloro aurate		*pm*	*w*	Zn Au Cl^3	51·5						3	1	12†	
Ditto platinate		*pm*	*y*	Zn Pt Cl	29·25									
Ditto palladiate		*nd*	*y*	Zn Pd Cl	23·5									
Ditto hydrargyrate		*nd*	*bn*	Zn Mr Cl	42				*w*					
Chlorate		*pm*	*w*	Zn Cl O^3	29				*w*					
Bromide		*nd*	*w*	Zn^2Bm^3	76				*w*	*d*	1	1		
Iodide		*m*	*w*	Zn^2I^2	112				*w*	*d*	1	1		
Iodo hydrargyrate		*pm*	*y*	Zn Mr I	65				*w*	*d*				

Iodate		*gr*	*w*	$Zn\,I\,O^3$	52			*w*	*d*	15·625	5·25	
Fluoride		*fk*	*w*	Zn^2F^5	29·5			*w*	*d*			
Phosphite		*pr*	*w*	Zn^2P^3	28							
Phosphate	1	*m*	*w*	$Zn\,P\,O^3$	24			*w*		100	113·8U	
	2	*m*	*w*	$Zn\,P^2O^3$	28			*w*		4·5	7·875	3·375†
	3	*pr*	*w*	$Zn^2P\,O^3$	32			*w*		4·5	5·25†	
Selenite	1	*pr*	*r*	Zn^2Se^3	46							
	2	*cr*	*w*	$Zn\,Se^2$	28							
Arsenite		*pr*	*w*	Zn^2As^3	44·5							
Sulpho Ditto		*pr*	*y*	$Zn\,As\,S^4$	33·5							
Hypo Ditto Ditto		*pr*	*or*	$Zn\,As\,S^5$	37·5							
Arseniate	1	*pr*	*w*	$Zn\,As\,O^3$	29·5							
	2	*pr*	*w*	$Zn\,As^2O^3$	39					7·25	7·825	10·125†
	3	*pr*	*w*	$Zn^2As\,O^3$	37·5							
Sulpho Ditto		*pr*	*or*	$Zn\,As\,S^2O^3$	37·5							
Chromate	1	*pr*	*or*	$Zn\,Cr\,O^2$	23			*w*		6·5	5·25T	
	2			$Zn^2Cr\,O^2$	31					6·5	10·5T	
Molybdate		*pr*	*bk*	$Zn\,Mo\,O^2$	28					9	5·25T	
Sulpho Ditto		*pr*	*bn*	$Zn\,Mo\,S^4$	36			*w*				
Tungstate		*pr*	*w*	$Zn\,W\,O$	20							
Sulpho Ditto		*pr*	*y*	$Zn\,W\,S\,O$	24			*w*				
Borate		*pr*	*w*	$Zn\,B\,O^3$	21							
Fluo Ditto		*pr*	*w*	$Zn\,B\,F$	13·5			*w*	*d*			
Carbonate	1	*pr*	*bk*	$Zn^2C\,O^2$	31					2·75	5·25	1·125T
	2	*pr*	*w*	$Zn\,C^2O$	18					2·75	5·25	3·375T
	3	*cr*		$Zn\,H\,C\,O$	15·25					2·75	10·5	2·25T
Bisulpho Ditto		*pr*	*w*	$Zn\,C\,S^2O$	23							
Cyanodide		*pr*	*w*	$Zn\,C\,Z$	14·5			*w ac*				
Sulpho Ditto		*pr*	*w*	$Zn\,C\,Z\,S$	18·5			*w*				
Ferro Ditto		*pr*	*w*	$Zn\,Fe\,C\,Z$	21·5							
Fulminate	1	*cr*	*w*	$Zn\,H\,C\,Z\,O$	18·75	350						
	2	*cr*	*y*	$Zn^2H\,C\,Z\,O$	22·75	350						
Antimoniate		*pr*	*w*	$Zn\,Sb\,O^3$	31			*w*				
Tellurate		*pr*	*w*	$Zn\,Te\,O$	20							
Sulpho Ditto		*sd*	*bn*	$Zn\,Te\,S\,O$	24							
Silicate		*pr*	*w*	$Zn\,Si\,O$	14							
Fluo Ditto		*pm*	*w*	$Zn\,Si^2F^3$	25·5			*w*				
Oxalate		*pr*	*w*	$Zn\,C\,O^2$	19			*w*		4·5	5·25	2·25T
Acetate		*pl*		$Zn\,C\,O^3$	23·25			*w*		6·75	5·25	7·875T
Lactate		*pm*		$Zn\,H\,C^3O^4$	33·25			*w*				

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											Acid.	Base.	Water.	
Formate				Zn H C^2O^3	26·25									
Tartrate		*sd*	*w*	Zn $H^2C^4O^5$	40·5				*w*		8·25	5·25T		
Potash Ditto		*m*	*w*	K Zn $H^2C^4O^5$	50·5				*w*					
Vinate		*nd*	*w*	Zn H C^2O^4	30·25									
Citrate		*cr*		Zn $H^6C^4O^6$	45·5						59	41		
Malate		*cr*		Zn H C^4O^4	35·25				*w*		9·5	5·25	1·6875T	
Ammonia Ditto		*cr*	*w*	Am Zn H C O										
Fungate		*pr*	*w*	Zn H C O					*w*					
Pyromucate		*m*	*w*	Zn $H^2C^9O^6$	59·5									
Succinate		*cr*	*w*	Zn $H^2C^4O^3$	32·5				*w*					
Benzoate		*nd*	*w*	Zn $H^5C^{14}O^3$	63·25				*w*					
Camphorate		*pr*	*w*	Zn H^3C^2O	18·75									
Suberate		*pr*	*w*	Zn H^4C O^2	20									
Oleate		*pr*	*w*	Zn $H^3C^{14}O$	54·75		200							
Butyrate		*pr*	*w*	Zn $H^{11}C^8O^3$	46·75									
Cholesterate		*pr*	*r*	Zn H C O										
Pinate		*fk*	*y*	Zn $H^{12}C^{11}O^2$	52									
Silvate		*pr*	*w*	Zn H C O					*a*					
Aspartate		*cr*	*w*	Zn H C O										
Sulpho naphthalate		*cr*	*w*	Zn $H^6C^9O^4$	56·5									
MANGANESE		*sd*	*gy*	Mn	7	8·013								
Oxide	1	*pr*	*bk*	Mn^2O^3	26									
	2	*pr*	*bk*	Mn O	11									
	3	*pr*	*r*	Mn^3O^2	29									
	4	*pr*	*bk*	Mn^5O^6	59									
	5	*pr*	*bl*	Mn^4O^7	56									
Sulphated Ditto		*ld*	*r*	Mn S^2O	19									
Muriated Ditto		*ld*	*bn*	Mn Cl^2O	29									
Carbonated Ditto		*pr*	*bn*	Mn C^2O^3	25									
Oxalated Ditto		*pr*	*ro*	Mn C^3O^2	24									
Tartrated Ditto		*pr*	*bn*	Mn H C^2O	17·25									
Citrated Ditto		*ld*	*bn*	Mn H C^3O	20·25									

Acid	1	*pr*	*sd*	$Mn\ O^5$	26·25							
	2			$Mn^2H\ O^2$	22·25							
Sulphite	1	*pr*	*bk*	Mn^4S^2O	40					4	4·5	2·8125
	2	*cr*	*gn*	Mn S	11							
Hypo Ditto		*pr*	*gn*	Mn S						5	4·5	5·625
Sulphate	1	*pm*	*r*	$Mn^2S\ O$	22	2·877		*w*		33·6	6·31	35·34
	2	*gm*	*r*	Mn S O^2	19			*w*	*d*	5	4·5	3·375
	3	*pm*	*r*	Mn S O	15			*w*	*d*	5	6·78	4·5
Hypo Ditto		*pr*	*gn*	Mn S O				*w*				
Potash Ditto	1	*cr*	*r*	K Mn S O	25					25	11	27T
	2	*pr*	*vi*	K Mn S^2O	29					9·5	11	5·625T
Ammonia Ditto	1	*pm*	*r*	$Am^5Mn\ S\ O$	28·5	1·93		*w*	*d*	9·5	7·125	7·875T
	2	*pr*	*r*	$Am^2Mn\ S\ O$	24					20	7·125	27T
Nitrate		*nd*	*w*	Mn Z O^3	22·5			*w*	*d*	6·75	4·50	7·875T
Chloride	1	*tb*	*pk*	Mn Cl	16			*w*	*d*	1	1	5T
	2		*gn*	Mn^2Cl^5	59							
	3	*gs*	*gn*	Mn^2Cl^3	41							
Chloro hydrargyrate		*pm*	*r*	Mn Cl Mr	41			*w*	*d*	1	1	4
Ditto aurate		*pm*	*y*	Mn Cl Au	32·5				*d*		1	6
Ditto platinate		*pm*	*bn*	Mn Cl Pt	28·25			*w*			1	6
Ditto palladiate		*cb*	*bn*	Mn Cl Pt	22·5			*w*				
Bromide		*pr*	*r*	Mn Bm	27			*w*				
Iodide		*pr*	*r*	Mn I	39							
Fluoride	1	*pr*	*gy*	Mn^2F^3	36·5			*w a*				
	2	*pr*	*w*	Mn F	11·5			*w a*				
	3	*pr*	*r*	Mn F^3	20·5			*w a*				
Phosphite				Mn P	11							
Phosphate		*pr*	*w*	Mn P O^3	23			*w*		4·5	5·625T	
Ferro Ditto		*pr*	*y*	Mn Fe P	18					13·5	13·5T	
Selenite	1	*cr*	*y*	Mn^2Se	24							
	2	*cr*	*y*	Mn Se	17							
Arsenite		*pr*	*y*	Mn As	16·5							
Sulpho Ditto		*pr*	*y*	Mn As S^4	32·5							
Hypo Ditto Ditto		*pr*	*r*	Mn As S^5	36·5							
Arseniate	1	*cr*	*w*	Mn As^2O^3	38					7·25	4·5	11·25T
	2			Mn As O^3	28·5							
Sulpho Ditto		*pr*	*r*	Mn As S^2O	28·5							
Chromate				Mn Cr O^2	22							
Molybdate		*pr*	*bn*	Mn Mo O^2	27							
Sulpho Ditto		*pr*	*bk*	Mn Mo S^2	27							
Tungstate		*pr*	*w*	Mn W O^2	23							
Sulpho Ditto		*lq*	*y*	Mn W S^2	23			*w*				

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											Acid.	Base.	Water.	
Borate				Mn B O^5	20									
Carburet		*sd*	*bn*	Mn C		2·982								
Carbonate		*pr*	*gy*	Mn^2C O^3	29						2·75	4·5	2·25T	
Bisulpho Ditto		*pr*	*y*	Mn C S^2O	22				*w*					
Cyanodide		*pr*	*w*	Mn C Z	13·5				*al ac*					
Sulpho Ditto		*pr*	*w*	Mn C Z S	17·5				*w*					
Ferro Ditto		*pr*	*w*	Mn Fe C Z	20·5				*ac*					
Cyanate				Mn H C Z O^2	21·75									
Fulminate		*m*	*w*	Mn H C Z O	17·75				*w ac*					
Antimonite		*pr*	*w*	Mn Sb	18									
Antimoniate		*pr*	*w*	Mn Sb O^5	30				*w*					
Tellurate		*pr*	*w*	Mn Te O	19				*o*					
Sulpho Ditto		*sd*	*bn*	Mn Te S	19									
Silicate	1			Mn Si O	13									
	2			Mn Si^3O^2	19									
Fluo Ditto		*pm*	*r*	Mn Si^2F^3	24·5				*w*					
Oxalate		*pr*	*w*	Mn C O^2	18						4·5	4·5	3·375T	
Acetate		*tb*	*w*	Mn H C O^5	22·25				*w*		6·25	4·5	4·5T	
Lactate		*pr*	*y*	Mn H C^3O^4	32·25					*ef*				
Tartrate		*pm*	*bn*	Mn $H^2C^4O^5$	39·5						9·25	4·5	2·25T	
Potash Ditto		*pr*	*w*	K Mn $H^2C^4O^5$	49·5				*s*					
Vinate		*pr*	*r*	Mn H C^2O^4	27·25									
Citrate		*pr*	*r*	Mn $H^6C^4O^6$	32·5									
Malate	1	*gm*	*y*	Mn H C^4O^4	35·25									
	2	*cr*	*r*	Mn^2H C^4O^4	42·25									
Fungate		*gm*	*y*	Mn H C O										
Succinate		*pm*	*r*	Mn $H^2C^4O^3$	31·5				*w*		6·25	4·5	3·375T	
Benzoate		*pm*	*r*	Mn $H^5C^{14}O^3$	62·25				*w*		15	4·5T		
Camphorate		*pl*	*r*	Mn H^3C^2O	17·75				*w*					
Suberate		*cr*	*w*	Mn H^4C O^2	19				*w*					
Pinate		*m*	*y*	Mn $H^{12}C^{11}O^2$	51									
Silvate		*pr*	*bn*	Mn H C O										
Sulpho naphthalate		*cr*	*y*	Mn H^6C^9S O^4	55·5				*w a*					

OBSERVATIONS.

Selenium has a metallic lustre, and in powder a deep red colour, but neither odour nor savour; yet when fusing, emits an odour similar to horse-radish in every instance. The *Selenious Acid* supplies a precipitate, *red*, to, sulphuric acid, sulphurous acid and zinc (when the temperature is raised); *white* to acetate of lead (sluggishly appropriated by nitric acid), to muriate of barytes (appropriated by muriatic acid), to protonitrate of mercury (appropriated by nitric acid, but indifferent to water), to nitrates of silver and of lime (appropriated by nitric acid); and *yellow* to sulphuretted hydrogen. The *Selenites* are either completely indifferent to water, or only sluggishly appropriated by it; but raised temperature decomposes them. On a charcoal support the blow-pipe flame changes them into *seleniurets;* or the element evolves, and the peculiar horse-radish odour is perceptible. *Selenic Acid* is appropriated by water to 512°, and above 536° is decomposed, and supplies a precipitate of the element to sulphurous acid; as likewise do the *Seleniates* after boiling in muriatic acid, which decomposes them, and the selenious acid evolves. The *Hydroselenic Acid*, also the Hydroseleniurets of the alkalies and of magnesia (solicited also by nitric acid), are appropriated by water, and appropriating its oxygen and that of the atmosphere, the element precipitates as a *red powder;* but the solution supplies one, *black*, to nitrate of silver, and acetate and protonitrate of lead.

Arsenic.—The salts of *Arsenious Acid* supply a precipitate, *white*, to salts of lead, chlorides of calcium and barium, and lime-water; *green* to sulphate of copper; *yellow* to nitrate of silver, hydrosulphuret of ammonia, and sulphuretted hydrogen (these two very sluggish in neutral solutions, but remarkably active when acidulated with muriatic acid, and temperature raised); and (acidulated) *metallic* to zinc. The *Arsenites* fused on a charcoal support by the blow-pipe supply the odour of garlic common to

metallic arsenic. Klaproth states that 1000 parts of water at the temperature of (60° F.) 12° R. appropriates only 3 parts of *Arsenious Acid;* but at (212° F.) 80° R. appropriates 73·5, of which 30 remain present after the solution is at (60° F. 12° R.

Chromium.—The protoxide salts are some *green*, others *amethystine;* and the double salts *amethystine* or *blue;* and in either flame of the blow-pipe render the flux *emerald green.* In solution, ferrocyanate of potash, and also boiling, only renders the tint darker, without causing a precipitate; they supply a precipitate, *green*, to alkalies, caustic and carbonate (those of potash and soda readily, of ammonia sluggishly, in excess re-appropriating the precipitate), indifferent to iron and zinc. After incandescence the protoxide is sluggishly appropriated by acids. *Chromic Acid* possesses bleaching properties. The salts supply a precipitate, *yellow*, to salts of lead, *lemon yellow* to salts of barytes, *red brown* to salts of silver, and *orange* to protosalts of mercury (by heat converted into protoxide of chromium).

Vanadium.—The oxide, by rise of temperature, combines with bases, and is appropriated by acids, the solutions usually being in colour *fine azure*, the crystals fine *blue;* very sluggishly colour water *green;* they supply a precipitate, *grey white*, to potash, soda, and carbonates (which air renders *brown*); *brown* to ammonia (indifferent to excess, but appropriated by distilled water); *red brown* to carbonate of ammonia; *blue* to bicarbonates; *yellow* to ferrocyanate of potash (by air rendered *green*); and *black* to infusion of galls and hydrosulphuret of ammonia. *Vanadic Acid* fuses at a red heat, orange; is resolved into oxide by sugar and alcohol; is readily at raised temperature appropriated by muriatic acid (orange coloured); and sluggishly by water, sulphurous, nitrous, and vegetable acid. When mixed with borax, or microcosmic salt, and on charcoal fused by the blow-pipe, the bead in the interior flame appears brown, and the exterior yellow, but fine green when cold, unless by the presence of tin rendered blue.

Molybdenum.—The oxide salts in solution are *red brown*, and become *blue* by raised temperature and appropriating the oxygen of the air; they supply a precipitate, *rust brown* or *chocolate*, to alkalies, caustic and carbonate, *brown* to hydrosulphuret of ammonia and sulphuretted hydrogen, very *dark* to ferrocyanate of potash, and *grey* to infusion of galls. *Molybdic*

Acid can be by any of the strong acids separated from the alkalies with which it is combined.

Tungsten.—*Tungstic Acid* is separated, likewise, by either nitric or muriatic acid, and is *yellow* when dry; it is readily appropriated by alkalies, but sluggishly by acids, and the portion too minute to form salts; tin appropriates a portion of the oxygen, and the *blue* residuum is supposed to be a mixture of the oxide and tungstic acid.

Antimony.—The oxide is indifferent to nitric acid, is appropriated readily by nitromuriatic acid, sluggishly by muriatic acid, which to water supplies a *white* precipitate, appropriated by dilute acid. The oxide salts (except the double) supply a precipitate, *white*, to water, the strong acids, the alkalies, caustic and carbonate, and solution (not crystal) of ferrocyanate of potash; *orange* to hydrosulphuret of ammonia, soluble in excess, and sulphuretted hydrogen. Most of the hydrated precipitates are indifferent to water, but appropriated by tartaric acid. On a charcoal support, with soda fused, the blow-pipe flame reduces the salt to a button of metallic antimony, when cold coated with white crystals of protoxide.

Tellurium, in solution, of nitric acid is indifferent to the addition of pure water; but of muriatic acid, supplies a precipitate, *white*, to alkalies, caustic and carbonate (by excess re-appropriated, element and salts): and *metallic*, to zinc, tin, copper, iron, sulphurous acid, and sulphite of ammonia. The oxide is appropriated by nitric and muriatic acids; forms salts with acids and alkalies, with hydrogen forms a colourless gas, by water appropriated, claret colour, and sulphuretted hydrogen odour; at a red heat effervescing, fusing, and afterwards sublimed.

Tantalum.—The protoxide (with difficulty determined by the blow-pipe) when incandesced is indifferent to acids, which, while raw, affect it sluggishly; the hydrate is readily appropriated by fluoric and oxalic acids; the latter to ferrocyanate of potash supplies a *yellow* precipitate. The (peroxide) *Tantalic Acid*, combined with alkalies, supplies a precipitate, *white*, to the strong acids and tin; likewise, *flocculent*, to alkalies, caustic and carbonate, *orange* to infusion of galls, and many of them to water.

Titanium.—The oxide (not readily detected by the blow-pipe in solution acid) supplies a precipitate, *dark olive-green*, to

ferrocyanate of potash. Boiling the chloride precipitates the oxide in so comminute a state that it easily permeates the filter; the solution, prior to boiling, when treated with zinc, is first *violet*, next *blue*, and then supplies a *slate blue* precipitate; and with tin is *amethystine*, and then follows a brown red precipitate. Boiling the muriatic solution of *Titanic Acid* supplies a copious precipitate, indifferent to hydrosulphuret of ammonia; but the acid, prior to boiling, supplies one, *white*, to alkalies, caustic and carbonate, *dark green* to hydrosulphuret of ammonia, *copper* coloured to ferrocyanate of potash, *orange* to infusion of galls, and *purple* to zinc bar.

Silicium.—The oxide (Silica or Silicic Acid) is indifferent to every acid and to water, except the hydrofluoric, with which it forms silicated fluoric acid gas; yet they sluggishly appropriate part of the hydrate, and (even when dilute) readily all the fresh precipitated jelly of silica obtained from the solutions by alkalies and carbonate of ammonia; decomposed by ammonia, also by boiling dry an acid solution, and to the dry mass adding muriatic acid; and by incandescence rendered indifferent to water and acids, except the phosphoric and boracic. With soda on a charcoal support it (and it only) will form a bead perfectly clear, and indifferent to mic. salt, in which it floats about.

Osmium.—By boiling, the oxide volatilises as the salts decompose; water readily appropriates it, and applied to the skin, stains it indelible to washing; by sulphuric acid is decomposed, the liquid being in colour successively *yellow*, *brown*, *green*, and *blue*; *yellow* by ammonia, *primrose* by carbonate of soda, *purple* to beautiful *blue* by infusion of galls; the solution supplies a precipitate, *black*: *flocculent* to alcohol and ether; and *black* to hydrosulphuret of ammonia and sulphuretted hydrogen; the peroxide is volatile, and easily sublimes.

Gold is very malleable, green by transmitted light, not oxidated by heat, appropriated by chlorine; mixed with soda on charcoal support easily reduced by blow-pipe flame, and purified by cupellation and quartation. The solution supplies a precipitate, a mixture of calomel and metallic gold, to protonitrate of mercury; *red purple*, followed by Cassius' powder, a *dark red powder*, to protomuriate of tin; *emerald green* to ferrocyanate of potash; *yellow*, sluggishly and partially, to alkalies, caustic and carbonate, *brown* to hydrosulphuret of

ammonia; but readily, in a *metallic* state, to zinc, iron, tin, several other metals, oxalates, protosulphate of iron, sulphuretted hydrogen, phosphorus, sulphurous, and oxalic acids.

Iridium, when platinum is present, is sluggishly appropriated by nitro-muriatic acid; and *alone*, extremely sluggishly, in comparison *sixteen times* more so than platinum, and *three hundred times* more so than gold; the liquid is iridescent, with a *brown* or *green* tinge, or *red*, with water; but is rendered colourless by sulphuretted hydrogen and alkalies; is indifferent to infusion of galls, ferrocyanate of potash, and carbonate of soda; but supplies a precipitate, *red brown*, to muriates of potash and ammonia, and carbonate of ammonia, *crystalline* to caustic alkalies, and *dark brown* to sulphuretted hydrogen and hydrosulphuret of ammonia, and *metallic* by the oxidable metals, but not by gold and platinum.

Rhodium.—The Oxide is appropriated by most strong acids, and the solution supplies a precipitate, *yellow*, to caustic alkalies (re-appropriated by excess), and *brown* to hydrosulphuret of ammonia and sulphuretted hydrogen, and one, *metallic*, to the oxidable metals indifferent to gold and platinum. The soda chloride is indifferent to alcohol, but readily appropriated by water.

Platinum is appropriated only by nitro-muriatic acid; and the solution supplies a double chloride to potash and ammonia, and ferrocyanate of potash; and a precipitate, *brown*, to iodide of potassium, hydrosulphuret of ammonia, and sulphuretted hydrogen (appropriated by excess); *yellow red* to protonitrate of mercury, *yellow* to prussiate of potash, and *crystalline* to the alkalies, caustic (appropriated by excess) and carbonate; *metallic* to the readily oxidated metals, but indifferent to gold and silver, cyanuret of mercury, and protosulphate of iron, is coloured *deep red brown* by protomuriate of tin; the double salts with potash and ammonia is sluggishly appropriated by water, yet indifferent to alcohol, while both readily appropriate that with soda; and that with ammonia, when at a high temperature, supplies the metal in a very fine spongy state, employed to ignite hydrogen gas. With the usual fluxes, the blow-pipe flame forms a button of metal, without discolouring the solvents.

Palladium.—The oxide is appropriated by nitric acid, the solution being a beautiful red; and water appropriates most of

the salts, likewise a beautiful red, and supplies a precipitate, *black* or *olive green*, to protomuriate of tin, *yellow brown* to ferrocyanate of potash, *yellow white* to cyanuret of mercury, *brown* to hydrosulphuret of ammonia and sulphuretted hydrogen, *orange* (when dry, *black*) to alkalies, caustic and carbonate, *metallic* to protosulphate of iron, and all the oxidable metals except silver, gold, and platinum. The double chlorides with the alkalies are indifferent to alcohol.

Mercury.—The *protoxide* solution supplies a precipitate, *white*, to the alkalies, caustic (and carbonate, when muriate of ammonia is present, otherwise it is *black*), phosphate of soda, ferrocyanate of potash, binoxalate of potash, *scarlet red* to chromate of potash, *greenish yellow* to iodide of potassium (or excess *black*, and by great excess re-appropriated), *yellow* to hydriodates, *black* to sulphuretted hydrogen and caustic alkalies, *white* to muriatic acid (indifferent to nitric acid, *black* by presence of ammonia), *white* to *black* to carbonate of ammonia, and *yellowish white* to *grey* to carbonate of potash or soda, and *metallic* (of the peroxide likewise) to zinc, iron, copper, sulphurous, and phosphorous acids; by the galvanic circuit, also the protomuriate of tin, to a *grey powder*, by heat formed into a globule of metal. Both oxides often being present in the nitric solution, the precipitates are *mixed*, the alkaline usually *plus* of peroxide, and the colours varied with plus of either. The oxide (Mr 4 O) supplies a precipitate, *dirty yellow*, to infusion of galls, to the peroxide, *orange yellow; white* (both) to ferrocyanate of potash and caustic ammonia, *grey* (*white*) to carbonate of ammonia (the precipitate by ammonia being re-appropriated as formed); *dirty green* (*lemon yellow*) to caustic potash and soda, *pale yellow* or *greenish* to carbonate potash, and soda (*red brown*), and *black* (both) to hydrosulphuret of ammonia and sulphuretted hydrogen; and when muriate of ammonia is present, *yellowish red* (in concentrated solutions) to chromate of potash, indifferent to muriatic acid, *cinnabar red* to iodide of potassium (re-appropriated by excess), *white* to potash and phosphate of soda, *black* to hydrosulphuret of ammonia carefully added and sulphuretted hydrogen, by agitation *white*, by excess very *black*. The salts of all the oxides are by heat volatile; and when mixed with either black flux or dry soda, and in a test tube exhibited to the blowpipe flame, the mercury sublimes as a grey powder, which by trituration supplies globules of the metal.

Silver is not oxidated by heat or air, nor absorbed by the bone-earth cupel used to separate other metals (except gold and platinum, which require quartation); but the blow-pipe flame applied to a mixture of the oxide and soda on a charcoal support supplies the metal as a bright button. The solution of the oxide supplies a precipitate, *white, flocculent* to muriatic acid, *violet* in air, indifferent to nitric acid, but readily appropriated by ammonia; yet neither solicit the *yellow white* to iodide of potassium, and both appropriate the *egg-yellow* to phosphate of soda, *dark chocolate* to chromate of potash, *yellow brown* to infusion of galls and caustic alkalies, *white* to carbonate alkalies and ferrocyanate of potash, *black* to hydrosulphuret of ammonia and sulphuretted hydrogen, and *metallic* to iron, zinc, copper, and (as an *amalgam*) to mercury.

Copper.—The protoxide is solicited by only few acids, and the almost colourless solutions formed readily appropriate the oxygen of the air, and supply a precipitate, *blue* to alkalies, caustic and carbonate, appropriated by excess, *red* to ferrocyanate of potash, *yellow grey* to red ferrocyanate, *black* to hydrosulphuret of ammonia and sulphuretted hydrogen; but used prior to exposure to the air, *yellow* to caustic alkalies, and primrose to the carbonated (appropriated by excess, and the solutions colourless), *dark brown* to hydrosulphuret of ammonia and sulphuretted hydrogen, and *metallic* to iron, zinc, tin, indifferent to sulphuric or muriatic acid. Nitric acid readily appropriates it, forming a deutoxide, by iron and zinc reduced to the metallic state. Boiling the hydrated deutoxide with caustic potash supplies a *black* deutoxide, which (in neutral solutions, and those of the weaker acids) supplies a precipitate, *blue* to caustic potash and soda, *greenish blue* to ammonia and carbonated alkalies, *brown* to infusion of galls, *red brown* to ferrocyanate of potash, *dark brown* to hydrosulphuret of ammonia and sulphuretted hydrogen, and *metallic* to zinc and iron. The salts mixed with soda on a charcoal support by the blow-pipe flame readily form a button of metal; but with borax, or mic. salt, a glass bead, in the interior flame *red brown*, and in the exterior *dark green*.

Uranium.—The protoxide is *dark green*, and becomes *black* on procelain, while the *orange* peroxide preserves its tint thereon. The protoxide salts in solution are *pale green*, and when immediately used supply a precipitate, *green* to alkalies, caustic and

carbonate, the latter appropriated by excess, and indifferent to carbonate of soda; but when exposed to light and air, or treated with nitric acid, changed into the peroxide, *yellow*, indifferent to iron, zinc, or tin; but which supplies a precipitate, *orange* to alkalies, caustic and carbonate, *red* to ferrocyanate of potash, and *black* to hydrosulphuret of ammonia.

Bismuth.—The oxide, *yellow*, is indifferent to sulphuric acid; the neutral salts are appropriated by water to a determined degree, and then plus of water causes a precipitate; the chloride solutions deposit a small portion of dichloride; the precipitate supplied is *white* to alkalies, caustic and carbonate, also carbonates of lime and magnesia, cold or boiling; *yellow* to infusion of galls, chromate, and ferrocyanate of potash, *brown* to iodide of potassium, *dark brown* to red ferrocyanate of potash, hydrosulphuret of ammonia, and sulphuretted hydrogen, and *metallic* to zinc or copper bar. By the interior blow-pipe flame, a brittle, easily broken metal button is formed of the salts mixed with soda, on a charcoal support, which appropriates a *yellow* powder coating.

Tin, though indifferent to the strongest nitric acid, is very powerfully solicited thereby on adding a little water. The protoxide salts in solution supply a precipitate, *white*, to muriatic and oxalic acids, to both ferrocyanates of potash, to phosphate of soda, to the alkalies, caustic and carbonate (that to ammonia by excess appropriated), *brown* to hydrosulphuret of ammonia, and sulphuretted hydrogen, *yellow*, to these two, of peroxide salts, but the colours of the others are alike to both oxides, *metallic* to zinc bar, and solution of silver, platinum, and gold (the Cassius' *purple*), and appropriates oxygen from solution of iron, copper, or mercury, which oxide is solicited by zinc. The incandesced peroxide of tin is indifferent to all acids, except muriatic; the solution is indifferent to the solution of gold, and supplies a precipitate, *metallic* to zinc bar, *yellow stiff jelly* to ferrocyanate of potash, indifferent to muriatic acid; and those to this last and the caustic alkalies, by excess most sluggishly re-appropriated. The salts with soda, on a charcoal support, by the interior blow-pipe flame are formed into a malleable button, by the exterior flame easily oxidated.

Lead.—The protoxide supplies a precipitate, *yellow*, to alkalies, caustic and carbonate, and at 212° to carbonate of

lime, to chromates and hydriodates; *white* to sulphuric acid and soluble sulphates (sluggishly appropriated by nitric acid), to *alkalies*, caustic and carbonate, *crystalline* to muriatic acid, appropriated by much water, and dilute nitric acid, *curdy* to muriates, appropriated by boiling water, and crystallising when cooling, *black* to hydrosulphuret of ammonia, and sulphuretted hydrogen, and *metallic* to zinc. The vegetable acid salts in solution mostly are indifferent to ammonia, or else this appropriates the lead as the solution is decomposed. The salts mixed with soda, or borax, on a charcoal support, by the blow-pipe flame is easily reduced to a button of malleable lead.

Cerium.—The protoxide salts are sluggishly appropriated by water; the solutions supply a precipitate, *white*, to alkalies, caustic and carbonate (appropriated by excess), phosphate of soda, oxalates, ferrocyanate of potash, infusion of galls, and (in neutral solutions) hydrosulphuret of ammonia, oxalates, oxalic acid (indifferent to excess); *crystalline* to sulphate of potash, indifferent to excess; and the common peroxide is *fawn* colour, while that by the blow-pipe exterior flame, from the salts with borax, or mic. salt, is *red brown*, but colourless in the interior, and likewise when cold.

Cobalt.—The protoxide salts are *red*, and acid solution supplies a precipitate *green* to ferrocyanate, *red-brown* to red ferrocyanate, and *pale rose* to binoxalate, of potash (sluggishly in air, re-appropriated by ammonia, caustic and carbonate), *blue* to *ash* to caustic alkalies and oxalates (appropriated by ammonia), indifferent to oxalic acid, *pink* to carbonated alkalies, *black* to hydrosulphuret of ammonia; but (likewise nickel salts) indifferent to carbonate of lime or magnesia, and bar of zinc or iron. Chlorine gas readily converts the protoxide in solution in water to peroxide; the chloride solution is *rose-red*—concentrated *blue*—and very dry, *rose-red*. The blow-pipe flame forms the salts and borax or mic. salt into a rich strong *blue* bead.

Nickel salts are beautiful *green*, except the evaporated dry chloride *orange*. The oxide, in ammonia, supplies a precipitate to caustic potash, this differing from cobalt; is likewise readily by chlorine gas converted into peroxide, much appropriated by the generated muriatic acid; the acid solution is indifferent to ammonia, but supplies a precipitate, *black*, to hydrosulphuret of ammonia, *whitish* to infusion of galls, *light green* to *grey* to ferrocyanate,

and *yellow* to red ferrocyanate of potash, *apple green* to alkalies, caustic and carbonate (excess appropriating the ammoniates, the caustic liquid *violet*, the carbonate *green*), to oxalates, and binoxalate of potash, indifferent to oxalic acid, but appropriated by ammonia, caustic and carbonate; and neutral solutions (cobalt also, most sluggishly), *black* to sulphuretted hydrogen. The blow-pipe flame forms the potash salts, with borax, into a *blue* bead, the others, *red* while hot, which fades, or entirely disappears, when cold.

Iron.—The salts appropriate oxygen rapidly from any medium; those of the protoxide are *green*, appropriated by carbonic acid (magnetic), and soliciting the oxygen of solution of gold leaves the metal to precipitate; at 60° F. indifferent to benzoates, succinates, also carbonate of lime or magnesia, each of which, at any temperature, solicits the peroxide, whose salts are *red brown*, as likewise are the precipitates they supply to alkalies, caustic and carbonate. The protoxide supplies a precipitate, *white*, to alkalies, caustic and carbonate, which rapidly becomes *dark brown* by appropriating the oxygen of the air, *blue* to ferrocyanate of potash (prussian blue), *pale* to the peroxide, in proportion to the oxygen, *purple* to *blue*, sluggishly to infusion of galls, *black* to hydrosulphuret of ammonia (likewise peroxide), and (neutral) sluggishly to sulphuretted hydrogen (the sulphur falling to peroxide), also of the other oxides, when much of the test is used; the second oxide supplies a precipitate to the alkalies, caustic and carbonate, *green*, varying in tint with the proportion of peroxide; this last supplying a precipitate, *dark blue* (ink colour) or *blue black* to infusion of galls, and *blood red*, not magnetic, to sulphocyanic and meconic acids. The salts with borax, or mic. salt, on charcoal support, by blow-pipe exterior flame forms a bead *deep red*, green in interior, yet only *pale* when cold, even with plus of iron.

Cadmium, at a raised temperature, is almost equally as soluble as mercury; the oxide, after incandescence, is *orange brown*, and when obtained in platinum vessel, can be well washed on the sides, to which it adheres. The oxide solution supplies a precipitate, *white* to alkalies, caustic and carbonate, and ferrocyanate, and binoxalate of potash, *yellow* to red ferrocyanate and infusion of galls, *orange* to hydrosulphuret of ammonia and sulphuretted hydrogen, distinguished from orpiment by fusing

into metal, and *metallic* to zinc. The salts mixed with soda, by the blow-pipe flame fused on charcoal, stains it and covers it with a *brown-red* powder.

Zinc, in oxide, heated is *yellow*, cold *white;* and in solution supplies a precipitate, *white*, to alkalies, caustic and carbonate (appropriated by excess), to binoxalates (indifferent to oxalic acid), to ferrocyanate of potash, infusion of galls, hydrosulphuret of ammonia, and (when neutral) to sulphuretted hydrogen. The salts mixed with soda, or nitrate of cobalt, by blow-pipe flame is fine *green*, on charcoal, coated *white* in exterior, and spread over the surface in the interior flame.

Manganese, in protoxide *pale rose-red*, peroxide *red* (formed by chlorine gas applied to the former) not appropriated by carbonic acid. The protoxide supplies a precipitate, *white*, to alkalies, caustic and carbonate (*brown* by peroxide), and air quickly rendering the former *brown*, while those of the bicarbonate remain *white*, indifferent to carbonate of lime and magnesia, but appropriated by carbonic acid and ammonia; *brown* to chloride of lime, and of *sulphur* to sulphuretted hydrogen. Fusion with carbonate of potash, or nitrate of potash, forms the *mineral chamelion;* and with borax, or mic. salt, on charcoal, the exterior flame of blow-pipe forms a bead *amethystine*, invisible in the interior, but when cold re-appearing.

ISOMORPHISM, ISOMERISM, ETC.

There are numerous proofs to warrant the conclusion of the most experienced chemists of our day, that the primary figure is the same of the atom of certain *classes* of acids, bases, and elements, which consequently may *replace*, or be substituted for, each other, without altering the figure of the crystal of the resulting compound. These classes originate the following Groups, arranged to shew already determined connecting links; in which every member of each, whether binary or other compound, which replaces another, has *identity of the number* of atoms in the whole, and of the respective component elements; equal numbers of which *replace* each other, yet the crystalline figure remains the same by combinative potency.

(The Groups are from PROFESSORS MILLER and JOHNSON; and the *arrangement* of substances and *notation* are altered to agree with the previous Tables. For these and the additions (*), I must bear the liability of error.)

1.

Chlorine †	Cl
Bromine	Bm
Iodine	I
Fluorine †	F
Manganese	Mn

(† Cl^2 and F^2, Berzelius)

2.

Chloric Acid	$HClO^3$
Bromic Acid	$HBmO^3$
Iodic Acid	HIO^3

3.

Hyperchloric Acid	HClO
Hypermanganic Acid	HMnO

4.

Sulphur	S
Selenium	Se
Chromium	Cr
Vanadium?	V
Manganese	Mn

5.

Peroxide of Lead	Pb^4O^3
——— Iron	Fe^4O^3
——— Manganese	Mn^4O^3
——— Cobalt	Co^4O^3
——— Nickel	Ni^4O^3
——— Zinc	Zn^4O^3
——— Copper	Cu^4O^3
Magnesia	Mg^4O^3?
Lime	Ca^4O^3?

6.

Sulphuric Acid	HSO^2
Selenic Acid	$HSeO^2$
Chromic Acid	$HCrO^2$
Vanadic Acid	HVO^2
Manganic Acid	$HMnO^2$

7.

Green Oxide of Chromium	Cr^4O^3
Red Oxide of Iron	Fe^4O^3
Brown Oxide of Manganese	Mn^4O^3
Alumine	Al^4O^3?
Titaniate of Protox. of Iron	Fe^7TiO^3

8.

Platinum	Pt
Copper	Cu
Bismuth	Bi
Lead	Pb
Cobalt	Co
Nickel	Ni
Zinc	Zn
Iron	Fe
Manganesium	Mn
Aluminum	Al
Magnesium	Mg
Calcium	Ca

9.

Barium	Ba
Strontium	Sr
Calcium	Ca
Lead	Pb

10.

Lime	Ca^2O
Barytes	Ba^2O
Strontian	Sr^2O
Yellow Oxide of Lead	Pb^2O

11.

Phosphorus	P
Arsenic	As
Antimony	Sb
Tellurium	Te

12.

(*) Phosphorus Acid	P^4O^3
Arsenious Acid	As^4O^3
Antimonious Acid	Sb^4O^3
Phosphoric Acid	P^4O^5 ?
Arsenic Acid	As^4O^5 ?
Antimonic Acid	Sb^4O^5 ?

13.

Oxide of Tin	Sn^2O
Titanic Acid	Ti^2O

14.

Potash	K^2O^3
Ammonia †	$AmZO^3$

(† $Am^2 + Aq^2$ Berzelius)

15.

Ammonia	H^3Z^2 ?
Arseniuretted Hydrogen	H^3As^2
Phosphoretted Hydrogen	H^3P^2
Soda	N^2O
Oxide of Silver	Ag^2O

16.

Sodium	N
Silver	Ag
Gold	An

And probably all other electro-positive Metals whose crystals have regular form.

17.

Molybdic Acid	Mo^2O^3
Tungstic Acid	W^2O^3

18.

Protoxide of Iron	Fe^2O
Green ditto Manganesium	Mn^2O
Brown ditto Chromium	Cr^2O
Alumine	Al^2O
Glucine	Be^2O
* Magnesia	Mg^2O
* Yttria	Y^2O
* Zirconia	Zr^2O
* Thoria	Th^2O

19.

Platinum	Pt
Palladium	Pd
Iridium	Ir
Osmium	Os
Iron	Fe
Copper	Cu
Bismuth	Bi
Lead	Pb

20.

Sulphate of Magnesia † ... $MgSO^2$
———— Zinc ... $ZnSO^2$
Seleniate of Zinc ... $ZnSO^2$
Sulphate of Nickel ... $NiSO^2$
(† MgH^6SO^{10}, Beudant)

21.

Sulphate of Soda ... NSO^2
Seleniate of Soda ... $NSeO^2$
Sulphate of Silver ... $AgSO^2$
Seleniate of Silver ... $AgSeO^2$

22.

Sulphate of Lime ... $CaSP^2$
Seleniate of Lime ... $CaSeO^2$

23.

Sulphate of Ammonia ... $AmSO^2$
———— Potash ... KSO^2
Seleniate of ditto ... $KSeO^2$
Chromate of ditto ... $KCrO^2$
Manganate of ditto ... $KMnO^2$
*Hyponitrite of ditto KZO^2
* Oxalite of ditto ... KCO^2

24.

Hyperchlorate of Potash ... KClO
Hypermanganate of ditto KMnO
Hyperchlorate of Ammonia AmClO
Hypermanganate of ditto AmMnO

25.

Sul. of Silver & Am $AmAgSO^2$
Seleniate of do. do. ... $SeAgSO^2$
Chromate of do. do. ... $CrAgSO^2$

26.

Sulphate of Nickel ... $NiSO^2$
Seleniate of do. ... $NiSeO^2$
———— Zinc ... ... $ZnSeO^2$

27.

Protosulphate of Iron ... $FeSO^2$
———— Cobalt ... $CoSO^2$
Proto Sulphate of Copper $CuSO^2$
———— and Nickel, $CuNiSO^2$
———— Magnesia, $CuMgSO^2$
———— Zinc $CuZnSO^2$
———— Zinc and Magnesia, $ZnMgSO^2$
———— Magnesia and Manganese $MgMnSO^2$
———— Soda ... NSO^2
Seleniate of ditto ... $NSeO^2$
Chromate of ditto ... $NCrO^2$

28.

Double Sulphates.

Potash Sul. of Magnesia $KMgSO^2$
Ammonia ditto ... $AmMgSO^2$
Potash ditto Manganese $KMnSO^2$
Ammonia ditto ... $AmMnSO^2$
Potash Sulphate of Iron $KFeSO^2$
Ammonia ditto ... $AmFeSO^2$
Potash Sul. of Nickel ... $KNiSO^2$
Ammonia ditto ... $AmNiSO^2$
Potash Sulphate of Zinc $KZnSO^2$
Ammonia ditto ... $AmZnSO^2$
Potash Sul. of Cobalt ... $KCoSO^2$
Ammonia ditto ... $AmCoSO^2$
Potash Sul. of Uranium ... $KUSO^2$
Ammonia ditto ... $AmUSO^2$
Potash Sul. of Copper ... $KCuSO^2$
Ammonia ditto ... $AmCuSO^2$
* Potash Sul. of Silver ... $KAgSO^2$
* Ammonia ditto ... $AmAgSO^2$
* Potash Sul. of Platinum $KPtSO^2$
* Ammonia ditto ... $AmPtSO^2$
* Soda ditto ... $NPtSO^2$

29.

* Potash Sul. of Manganese KMnSO
Ammonia ditto ... AmMnSO
Potash do. Zinc ... ... KZnSO
Ammonia ditto ... AmZnSO

Potash ditto Cadmium ... KCdSO
Ammonia ditto ... AmCdSO
Potash ditto Iron ... KFeSO
Ammonia ditto ... AmFeSO
Potash ditto Nickel ... KNiSO
Ammonia ditto ... AmNiSO
Potash ditto Cobalt ... KCoSO
Ammonia ditto ... AmCoSO
Potash ditto Cerium ... KCoSO
Ammonia ditto Tin ... AmCaSO
Potash ditto Silver ... KAgSO
Ammonia ditto ... AmAgSO

30.

Anhydrite ... ... $CaSO^2$
Heavy Spar ... ... $BaSO^2$
Celestine ... ... $SrSO^2$
Sulphate of Lead ... $PbSO^2$
* ——— Lithia ... LSO^2
* ——— Glucina $BeSO^2$
* ——— Zirconia ... $ZrSO^2$

31.

Alums.

Potash Sul. of Alumine ... KAlSO
Ammonia ditto ... AmAlSO
Soda ditto ... NAlSO
Potash Sulphate of Iron KFeSO
Ammonia ditto AmFeSO
Ditto Manganese ... AmMnSO
Potash Sul. of Chromium KCrSO
Ammonia ditto ... AmCrSO
Potash Silicate of Alumine KAlSiO

32.

Rock Salt ... ... NCl
Chloride of Silver ... AgCl
Fluoride of Sodium ... NF

33.

Double Chlorides.

Ammonia Chloride of Antimony, AmSbCl
——— Nickel AmNiCl
——— Cobalt AmCoCl
Ammonia Chloride of Lead AmPbCl
——— Copper AmCuCl
——— Silver AmAgCl
——— Mercury AmMrCl
——— Osmium AmOsCl
——— Iridium $AmIrC_1$
——— Palladium, AmPdCl
——— Platinum, AmPtCl

———

Potash do. Osmium KOs^2Cl^3
——— Iridium ... KIr^2Cl_3
——— Palladium KPd^2Cl^3
——— Platinum KPt^2Cl^3

———

Soda Chloride of Gold ... NAnCl
——— Rhodium NRCl
——— Iridium ... NIrCl
——— Platinum NPtCl

34.

Native Antimony ... Sb
——— Arsenic ... ... As
Tellurium ... ... Te

35.

Dark Ruby Silver
Light do. do.

36.

Arseniate of Lead ... PbAsO
Phosphate ditto ... PbPO
Apatite ... ... CaPO

37.

Arseniate of Potash ... KAsO
Phosphate ditto ... KPO
Arseniate of Ammonia ... AmAsO
Phosphate ditto ... AmPO

38.

Arseniate of Soda ... NAsO
Phosphate of ditto ... NPO

39.

Biphosphate of Soda ... NA^2O
Biarseniate of ditto ... NAs^2O

40.

Biphosphate of Ammonia AmP^2O
Biarseniate ditto ... $AmAs^2O$

41.

Biphosphate of Soda ... N^2P^2O
Biarseniate ditto ... ... N^2As^2O

42.

Vivianite
Cobalt Bloom

43.

Molybdate of Lead
Tungstate ditto
——— Lime

44.

Spinelle ... ... MAl^2O^4
Pleonaste ... ... $MFeAl^2O^5$
Gahnite... ... $ZnMFeAl^2O^6$
Chromite of Iron ... $MFe^2Cr^2O^8$
Franklinite ... $ZnFe^2Mn^2O^8$
Magnetic Iron Oxide Fe^3O^4
Titanic Iron Oxide ... Fe^2TiO^6

Abich (grandson of Klaproth) states that these are octahedral, and can be artificially formed by the moist way.

45.

Garnets.

Grossular $A^2Si^2Ca^3O^{10}$
Almandine ... ... $A^2Si^2Fe^3O^{10}$
Melanite ... $Fe^2Si^2Ca^3O^{10}$
Magnesian Garnet ... $A^2Si^2Mn^3O^{10}$

46.

Specular Iron Oxide ... Fe^2O^3
Titanic Iron Oxide ... $FeTiO^3$
Corundum ... ... A^2O^3
Peroxide of Manganese ... Mn^2O^3

47.

Oxide of Tin ... ... SnO^2
Rutile ... ... TiO^2

48.

Calc Spar ... ... $CuCO^3$
Bitter Spar ... ... CaC^2MO^6
Carbonate of Magnesia and Iron, $MFeCO^4$
————— Iron ... $FeCO^3$
Manganese Spar ... $MnCO^3$
Zinc ditto ... ... $ZnCO^3$
Magnesia ditto ... MCO^3

49.

Arragonite ... ... $CaCO^3$
Witherite ... ... $BaCO^3$
Strontianite ... ... $SrCO^3$
Carbonate of Lead ... $PbCO^3$

50.

Acetate of Lead ... ... $PlHCO^3$
————— Barytes ... $BaHCO^3$
Olivine ... ... M^2SiO^4
Hyalosiderite ... $M^3Fe^3SiO^5$
Crystals in Slags ... Fe^3SiO^4

51.

Pyroxene ... $Ca^3M^3Si^2O^5$
Bisilicate of Manganese $Mn^3Si^2O^4$

52.

Tremolite ... ... $CaM^3Si^3O^8$
Anthophyllite ... $FeM^3Si^3O^8$

DIMORPHOUS (*Two* Forms).

1. Elementary

Sulphur
Carbon

2. Two Elements

Bisulphuret of Iron

3. Three Elements

Carbonate of Lime
————— Lead
Biphosphate of Soda

4. Four Elements	5.
Garnet, or	Sulphate of Nickel
Idocrase	——— Magnesia
	——— Zinc
	Seleniate ditto

The Groups numbered 19, 31, 32, 33, 44, 45, supply *octahedral* crystals; 25, 26, 37, 43, 47, 49, *square prismatic;* 34, 35, 36, 46, 48, *Rhombohedral;* 20, 21, 23, 24, 30, 38, *prismatic;* 22, 27, 28, 29, 39, 40, 41, 42, 50, 51, 52, *oblique prismatic;* and some varieties are *doubly oblique prismatic.* The Isomorphism of the several groups of Elements, except the four which commence group 1, is assumed from that of their compounds with the like number of atoms of oxygen. And the links which reciprocally connect groups, 1, 4, 8, 9, render very probable the isomorphism of these and all other Elements.

ISOMERIC SUBSTANCES.

These have the same Component Elements with like proportions, and the same atomic weight:—

1. The Phosphoric and Paraphosphoric Acids and their salts.
2. The Tartaric and Paratartaric (Racemic) Acids.
3. The Peroxide of Tin in the two states.
4. Silicic Acid and Silicates, native and incandesced.
5. Antimonites and Antimoniates, also after incandescence.
6. Tungstic Acid and Oxide in their two states.
7. Telluric Acid and Oxide in their two states.
8. Cyanuric Acids, soluble HCO [* $CZHO^2$], and insoluble HCO [* CZO^2].
9. The Cyanic and Fulminic Acids, HCO [* CZO] and HCO [* ZCHO].
10. Oil of Wine and Faraday's light liquid Carbo-hydrogen, H^4C^4.
11. The Pyrotartaric and Pyroparatartic acids.
12. The Phosphate of Copper in both states.
13. The Bisulphuret of Mercury in both states.
14. The Phosphoretted Hydrogen in both states—that which inflames spontaneously in air, and that entirely indifferent to it.
15. The Iodide of Mercury in the two states.
16. The Chloride of Lithium in the two states.
17. The Mellate of Ammonia in the two states.

METAMERIC SUBSTANCES.

These have the same elements in precisely like proportions, yet they compose substances *completely different* in their qualities.

1. { Cyanuric Acid.....HCO } Two atoms of the former
   { Hydrous Cyanic Acid .....HC } = three of the latter.
2. { Naphthaline..... H^2C^5 at 4·528 density of vapour } ∴ 3 vols. of naphth.
   { Paranaphthaline H^2C^5 at 6·741 ditto } = 2 do. paranaphth.
3. { Oil of Bitter Almonds..... } $H^6C^{14}O^2$ Wöhler and Liebig.
   { Camphor deposited therein }
4. { Asparagin..... .....$H^{12}Z^3C^6O^4$
   { Aspartate of Ammonia.
5. { Urea..... } $H^4Z^2C^2O^2$
   { Cyanate of Ammonia with one atom of water.. } $H^4Z^2C^2O^2$

POLYMERIC SUBSTANCES.

These have the component elements in the *like ratio*, but not *the precisely same number.*

1. Paraffin H^2C^2—Olefiant gas H^2C^2—Trito-carbo-hydrogen (?) $H^{\ddot{2}}C^7$—Oil of Wine H^4C^4—Faraday's Carbo-hydrogen H^4C^4.
2. Oils of Lemon and of Turpentine, and Camphogene H^8C^{10}—*Dumas.*
3. Cyanogen, and the black residium from incandesced Cyanide of Mercury.
4. Arabine and Cerasine $H^5C^6O^5$—*Guerin.*
5. Phosphoric and Paraphosphoric—and Metaphosphoric Acids.
6. Cane Sugar, Diabetes sugar, Lignin.
7. Sugar of Milk, Manna, Gum Arabic.

Dumas entertains the opinion, that those Metals which have like atomic weights, similarity of forms, localities, chemical properties, or other simple relation to each other, are in fact *isomeric* or *polymeric* modifications of the same elements; thus—

	Atoms.		Atoms.		Atoms.
Cobalt	368·99	Platinum	1233·36	Molybdenum	598·5
Nickel	369·67	Iridium	1233·36	½ Tungsten	596·5

Doubtless many others will present themselves to the inquirer; and their comparison and close investigation may at length suggest trains of research, productive of interesting and important results.

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